Geology and Mineral Deposits of the Jefferson City Quadrangle, Jefferson and Lewis and Clark Counties, Montana

By GEORGE E. BECRAFT, DARRELL M. PINCKNEY, *and* SAM ROSENBLUM

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GEOLOGY AND MINERAL DEPOSITS OF THE JEFFERSON CITY QUADRANGLE, JEFFERSON AND LEWIS AND CLARK COUNTIES, MONTANA

By George E. Becraft, Darrell M. Pinckney, and Sam Rosenblum

ABSTRACT

The Jefferson City quadrangle, in Jefferson and Lewis and Clark Counties, Mont., is near the northeastern margin of a mountainous area of moderate relief called the Boulder Mountains. Altitudes range from 4,880 to 8,150 feet. The quadrangle was mapped as part of a general study of the geology and mineral deposits in and around the Boulder batholith.

The oldest rocks in the quadrangle are the middle and upper units of the Elkhorn Mountains volcanics of Late Cretaceous age. The middle unit is characterized by quartz latitic welded tuffs and the upper unit by well-bedded sedimentary tuffs. Both units are cut by dikes of rhyodacite porphyry. During Late Cretaceous or early Paleocene time, the Elkhorn Mountains volcanics were intruded by the Boulder batholith; they are now exposed in a large roof remnant near the center of the quadrangle and in many smaller remnants.

Most of the quadrangle is underlain by batholithic rocks that constitute the Butte quartz monzonite. These rocks, which are mainly quartz monzonite but include some granodiorite, fall within a narrow range in chemical and mineralogical composition and are believed to belong to a single large pluton. Slight but mappable differences in grain size, texture, and mineralogical composition are attributed to intermittent movement and mixing between fractions of the magma that had reached different degrees of crystallinity near the contacts with overlying rocks.

Batholithic rocks that are slightly younger than the Butte quartz monzonite include alaskite, alaskite porphyry, aplite, pegmatite, granite porphyry, and a few fine-grained, porphyritic dike rocks of diverse composition. Alaskite is the most abundant; it forms dikes and a few large, irregular bodies in Butte quartz monzonite and in the prebatholithic rocks near the margins of the batholith.

The youngest consolidated rocks in the quadrangle are quartz latite of Oligocene age and rhyolite of Oligocene(?) or Miocene(?) age. These rocks were emplaced after a long period of erosion during which most of the Elkhorn Mountains volcanics were removed and a mature erosion surface was developed on the underlying rocks of the batholith. The quartz latite occurs as tuff, dikes, breccia bodies, and probably flows. Small bodies of rhyolite are mostly flow remnants; a large body of rhyolite on Red Mountain is probably mostly intrusive.

During the Pleistocene epoch, most of the stream valleys in the western part of the quadrangle were occupied by glaciers. Glacial erosion modified the topography only slightly, but glacial deposits are widespread. Ground moraine is extensive, and the beds of all major eastward-flowing streams contain thick accumulations of outwash gravel. After the ice retreated, three landslides occurred near Rimini on valley walls steepened by glacial erosion. Other Recent deposits include talus below outcrops of volcanic rocks and alluvial deposits along most streams.

The major structural features in the quadrangle are a broad southeast-plunging faulted syncline in the prebatholithic Elkhorn Mountains volcanics; many joint sets in the batholithic rocks; large, steeply dipping alaskite dikes that trend dominantly northeastward; shear zones that trend generally eastward and contain quartz veins; chalcedony veins and vein zones that trend northeastward; quartz latite dikes that trend north to northeast; nonmineralized faults of different trends; and probable faults indicated by topographic lineaments. The persistent northeastward trends of many structural features are probably the result of recurring regional forces active since emplacement of the batholith and possibly even before.

Ore deposits in the quadrangle have been valuable chiefly for silver and lead, and, to a lesser extent, for gold, zinc, and copper. Mining was most active before 1900. Six mining districts have produced ore valued at more than $80 million; they are served by a lead smelter at East Helena and are crossed by good roads, a railroad, and power lines. The Alta and Comet mines have been the most productive mines in the Boulder batholith outside of Butte. A few small uranium deposits have been discovered since 1949, and a little uranium ore has been shipped.

The mineral deposits are almost entirely in veins along sheared or brecciated zones. Two distinctly different types of veins are distinguishable, and, in general, they occur in different parts of the quadrangle. Coarsely crystalline quartz is prevalent in one type; chalcedony and microcrystalline quartz are prevalent in the other. Most of the base and precious metals occur as sulfide ore bodies in quartz veins, either intermixed with the quartz or in the adjacent intensely altered rock. Many of the ore bodies are oxidized near the surface. In a few places tourmaline is a major constituent of the quartz veins, and most veins contain late primary carbonate minerals.

The quartz veins were formed largely by replacement of rock adjacent to fractures in shear zones, and the structure of a vein therefore reflects the original structure of the fracture system, ranging from a single joint to a wide, complex shear zone. Distinct mineral assemblages can be recognized in the quartz veins. The chalcedony veins, which commonly have prominent reeflike outcrops, are almost barren of sulfide minerals, but they contain most of the small uranium deposits that have been found. In a few veins, coarsely crystalline quartz and chalcedony are about equally abundant. Some of these quartz-chalcedony veins contain small deposits of base and precious metals and uranium.

Wallrock is altered largely to sericite near the quartz veins and to clays farther away. The alteration is similar to that at

Butte. Wallrock near chalcedony veins is altered mostly to clays.

All the veins are younger than any rocks of the batholith. The quartz veins, and probably most of the chalcedony veins also, are older than the quartz latite and rhyolite.

Some ore deposits in the quadrangle are not in veins. A mineralized breccia pipe and a deposit that may be either a mineralized tuffaceous conglomerate or another breccia pipe have been found. Placer deposits of gold have been worked, particularly along Clancy and Prickly Pear Creeks. A few small bog deposits of manganese and native copper also occur.

INTRODUCTION

The Jefferson City quadrangle is almost entirely in Jefferson County in western Montana; a small area of Lewis and Clark County is included in the northwest corner of the quadrangle. The north boundary is about 10 miles south of Helena and the south boundary is about a mile north of Boulder (fig. 1). In the past, several thriving settlements existed in the area—Jefferson City, Corbin, Wickes, Rimini, Gregory,

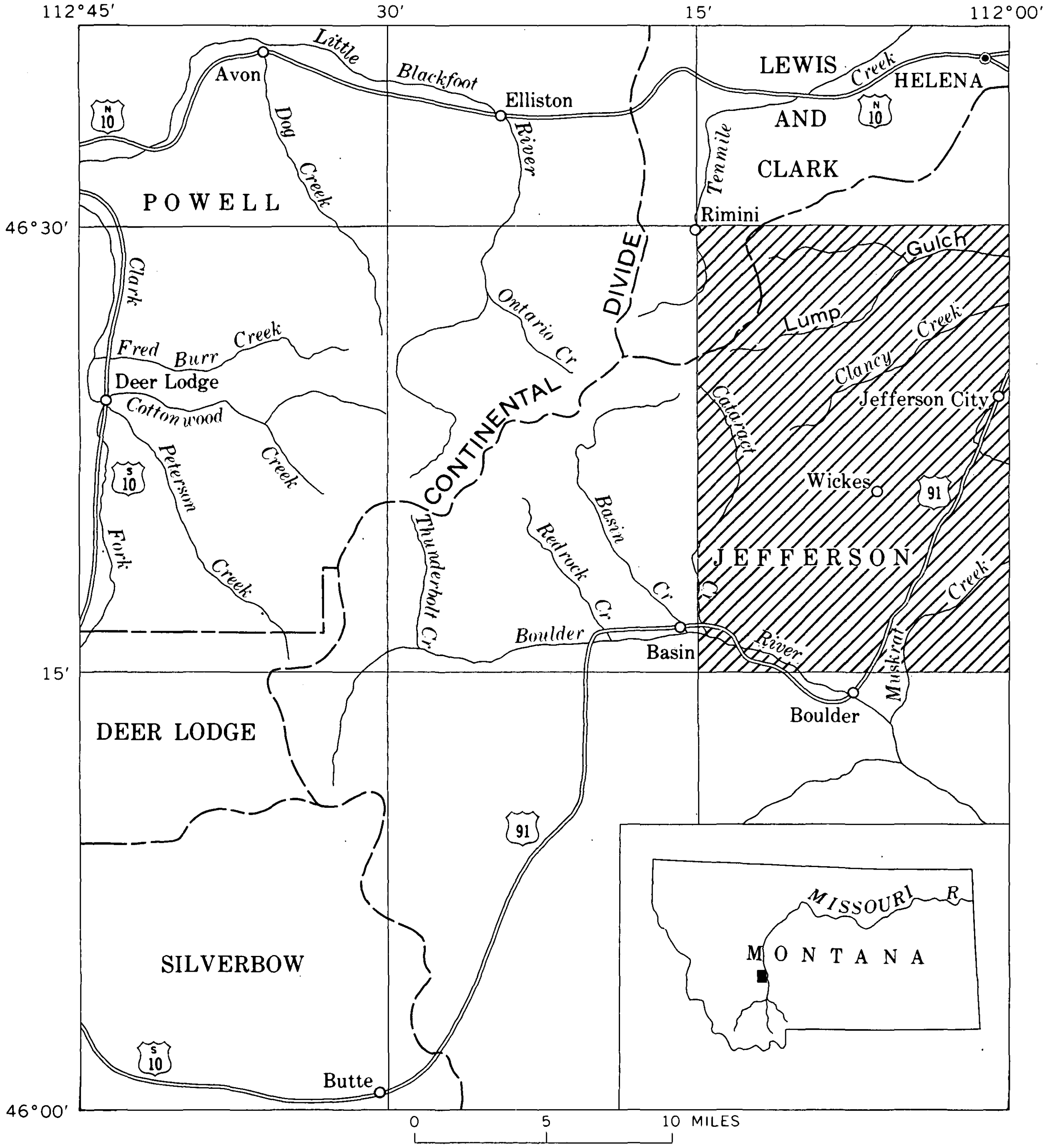

FIGURE 1.—Index map showing location of the Jefferson City Quadrangle.

and Comet. With the exception of Jefferson City, which still has a few stores, the settlements were largely abandoned as mining activity declined.

U.S. Highway 91 and a branch of the Great Northern Railroad cross the southeastern part and the southwest corner of the quadrangle. Many graded county roads that in general follow the main valleys make most of the area readily accessible.

The area is drained by three major streams. Prickly Pear Creek and its three main tributaries, Spring Creek, Clancy Creek, and Lump Gulch Creek, drain the central and northeastern part; Tenmile Creek drains the northwest corner; and the Boulder River and its tributaries Cataract Creek, High Ore Creek, and Muskrat Creek drain the southern part.

The climate of the region is semiarid, and the precipitation is mostly in the form of snow in the winter months and snow and rain in the spring and fall. Frost and snowstorms are common as late as June and as early as September, and even in July and August brief snow flurries occasionally occur. Usually the summer precipitation is restricted to a few thunderstorms. Nevertheless, all the major streams in the quadrangle have a continuous flow throughout the year. The Tenmile Creek drainage above the settlement of Rimini is used as the main source of water supply for the city of Helena; Chessman Reservoir in the Jefferson City quadrangle is an artificially dammed lake used in this system as a water storage area. Water is taken from Banner Creek and carried by an aqueduct around Red Mountain to Chessman Reservoir, where it is stored until needed during the summer. Then, water released at the dam on the west side of the reservoir flows down Beaver Creek to an intake near Rimini.

The Jefferson City quadrangle was mapped (pl. 1) during the summers of 1950 through 1953 as part of a general study of the geology and mineral deposits in and around the Boulder batholith. In 1950, W. A. Roberts and A. J. Gude III (1953a and 1953b) mapped two small areas in which uranium deposits had been discovered the previous year. During the summer of 1951, G. E. Becraft, Daniel Y. Meschter, and E. B. Gross mapped the Comet area in the southwestern part of the quadrangle (Becraft, 1953). Mapping was subsequently completed by Becraft, Rosenblum, Pinckney, Meschter, Robert F. Gosman, M. R. Klepper, and R. A. Weeks. An index to the areas mapped is included on plate 1. Payome Aranyakanon assisted Becraft and Rosenblum during the summer of 1952, and Clarence Fidler assisted during the summer of 1953. Most of the mapping was carried out on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission. The geology of a large part of the quadrangle was plotted on topographic maps enlarged to a scale of 1:12,000 from preliminary topographic maps prepared at a scale of 1:24,000 by Fairchild Aerial Surveys for the U. S. Bureau of Reclamation. The remaining area was mapped at a scale of 1:24,000.

George J. Neuerburg, U.S. Geological Survey, spent four weeks during the summers of 1951 and 1952 studying field relations of the alaskite in the Boulder batholith and subsequently studied samples in the laboratory. Most of the information on alaskite used in this report was compiled by Neuerburg (written communication, 1954).

We are indebted to the many individuals and companies who freely gave information on mining properties within the quadrangle, particularly John Giulio, R. H. Mills, Frank Rowe, Alfred Nugent, A. T. Cooper, J. S. Hampton, A. H. Eiselein, Kenneth Curtis, Wade V. Lewis, Wayne Hinman, Dewey Hinman, Buford Miles, George Mayer, Merlin Sparrow, A. M. Smith, C. E. Pew, Louis Peura, S. N. Kesten, Leahey Leasing Company, Uranium Corporation of America, and the Anaconda Company. Production data on many mines were supplied by the U.S. Bureau of Mines.

We are particularly indebted to Miss Nancy C. Pearre for her invaluable assistance during the writing of the manuscript, and we acknowledge this assistance with deep gratitude.

Several geologists have made reconnaissance geologic studies of areas that include the Jefferson City quadrangle. The earliest geologic work on the igneous rocks of the area was done in 1883 by Lindgren (1886). He briefly described some of the rocks and applied the name "Jefferson granite field" to them. Weed (1899), in a study of the Butte mining district, named the Boulder batholith after the mountains in which it is exposed. Knopf's report (1913) on the Helena mining region includes descriptions of the geology and ore deposits of some of the mining districts in the quadrangle and contains a reconnaissance map that includes the Jefferson City quadrangle. This report aided greatly in our understanding of the general relations of the rock types and supplied considerable information on mines inaccessible to us. Pardee and Schrader (1933) also briefly described the geology and some of the mines in the quadrangle. Billingsley (1915) and Billingsley and Grimes (1918) include descriptions of the geology and mineral deposits of the Boulder batholith. Detailed studies of a number of mining properties have been made by geologists of the U.S. Atomic Energy Commission.

This report is one of a series of descriptive reports on quadrangles in and around the Boulder batholith (fig. 1), all of which have been mapped as part of the same detailed study. Much of the interpretation of the geology here described must be deferred until the entire batholith has been mapped.

SURFACE FEATURES

TOPOGRAPHY

The Jefferson City quadrangle is near the northeastern margin of a mountainous area of moderate relief locally called the Boulder Mountains. The quadrangle lies between the Elkhorn Mountains on the east and the broad, high surface in the vicinity of the Continental Divide to the west. The area is mountainous but the topography is not rugged; most of the ridges are smoothly rounded and are about 1,000 feet above the major valleys. The maximum relief is about 3,900 feet. The highest point in the quadrangle is on Red Mountain and has an altitude of 8,150 feet above sea level. Many ridges are between 7,500 feet and 8,000 feet above sea level. A prominent topographic feature is the Occidental Plateau in the west-central part of the quadrangle. This high, moderately rolling surface reaches an altitude of about 7,800 feet. The eastern slope of the plateau, in which several small cirques have been cut, is very steep, but the western slope is gentle.

The drainage is well integrated and most streams are in mature valleys, but the Boulder River, which is the largest stream in the quadrangle, flows in a youthful canyon with moderately steep walls. The river has cut about 800 feet below a considerably dissected, moderately rolling surface that probably was similar to the Occidental Plateau and may have been formed about the same time as the surface of the Plateau. Several tributaries of the river show evidence of at least one period of rejuvenation—sharp youthful valleys near the river and broad mature valleys near the headwaters, knick points, and sparse terrace deposits. Boomerang Creek has two knick points, one about 600 feet and the other about 1,000 feet above the Boulder River.

The origin of the broad Boulder Valley is not known. Muskrat Creek is the only significant stream flowing through the valley, and although the stream was larger during the Pleistocene, it could not have formed the large valley. The valley floor is covered with alluvium that grades to the west into mass wastage deposits on a surface resembling a pediment. Possibly the valley was formed by downfaulting, but no large faults were observed.

PLEISTOCENE FEATURES

During the Pleistocene, glacial ice covered most of the highlands along the west margin of the Jefferson City quadrangle, and most of the stream valleys in the same area were occupied by glaciers. The ice was the eastern edge of an ice sheet that covered most of the adjoining Basin quadrangle (Ruppel, 1962). The major accumulation of ice affecting the Jefferson City quadrangle appears to have been in the area north of Cataract Basin in secs. 21 and 28, T. 8 N., R. 5 W. (pl. 1) and in the area just to the west in the Basin quadrangle. From there, glaciers moved southward, eastward, and northward along stream valleys. Typical U-shaped valleys and cirques are absent, but glacial deposits are widespread.

Ice moved southward from the accumulation area by way of Cataract Creek to within about 2½ miles of the Boulder River. Small glaciers occupied all the tributary valleys of the creek. Those flowing from the east in Hoodoo Creek and Snowdrift Creek were probably smaller than those flowing from the west because these creeks drain the relatively gentle western slope of the Occidental Plateau, which was only partly covered by a thin accumulation of ice.

Eastward from the center of accumulation, ice moved down Lump Gulch and both forks of Quartz Creek. These glaciers were joined by several smaller tributary glaciers from cirques in sec. 15, T. 8 N., R. 5 W.; Frohner Meadows; the vicinity of Park Lake; and possibly Forest Lake. Before the Pleistocene the drainage from Frohner Meadows was down the North Fork of Quartz Creek; Lump Gulch Creek captured this drainage during the Pleistocene. The present drainage divide is a broad, low ridge of glacial moraine that rises only about 15 feet above the valley floor.

Ice moved northward from the accumulation area in sec. 21 into the Banner Creek glacier, which flowed into Tenmile Creek glacier about a mile south of Rimini. Two cirques from which ice also flowed into Banner Creek were cut on the western and southwestern flanks of Red Mountain. Another tributary of the Tenmile Creek glacier formed in a cirque on the southeast flank of Red Mountain and flowed down Beaver Creek, joining the Tenmile Creek glacier at Rimini. Ice also accumulated in sections 11 and 12 south of Chessman Reservoir; if a glacier formed, it too, must have moved westward down Beaver Creek, because no evidence of glaciation was noted in Buffalo Creek or Corral Gulch east of the reservoir.

Although glaciation was widespread, glacial erosion modified the pre-Pleistocene topography only slightly. Glacial erosion was most extensive on the eastern slope of the Occidental Plateau, where typical small alpine cirques were cut at the heads of Kady Gulch and Clancy Creek. Glaciers probably persisted longer in these valleys than elsewhere, and even today large snowbanks remain on the lips of the cirques well into the summer, apparently because prevailing westerly winds during the winter blow the snow over the plateau to build huge drifts in the cirques. Similar conditions during the Pleistocene could possibly account for the greater glacial erosion on the eastern side of the plateau.

Extensive moraines were deposited by the glaciers. The moraines are well preserved in the North and South Forks of Quartz Creek and especially in Kady Gulch.

Thick accumulations of outwash gravel were deposited in all major eastward flowing streams. Gravel fill along Clancy Creek about 6 miles southwest of Clancy, for example, is as much as 35 feet deep. The gravel that fills Wood Chute Gulch to a depth of at least 30 feet near Wickes is probably an outwash deposit from a glacier that formerly occupied the head of the gulch. The deposit extends along the valley about 4 miles and is about half a mile wide at its widest point. Its surface is smooth except where entrenched by recent stream valleys to a depth of about 30 feet. Two pebble counts made by Paul Myers, U.S. Geological Survey, indicate that all the types of rock in the gravel crop out along Wood Chute Gulch. Low terrace deposits of fine gravel and sand along Prickly Pear Creek and lower Lump Gulch may also be outwash deposits. They were not mapped individually because they are generally small and poorly exposed.

East of the Jefferson City quadrangle, the Elkhorn Mountains were glaciated during two periods—an "Early" period, and a "Late" period during which glaciers were less extensive (Klepper, Weeks, and Ruppel, 1957). Glaciers of the "Early" period may have extended into the Jefferson City quadrangle in the Muskrat Creek valley; if so, any moraine deposited was subsequently removed by erosion. A "Late" period terminal moraine was deposited in Muskrat Creek valley about a mile east of the Jefferson City quadrangle, but "Late" glaciers did not extend into the quadrangle.

Glaciation may have occurred during two periods in the Jefferson City quadrangle also, or possibly during only a single period, with small glaciers persisting in the headwaters of Kady Gulch, Clancy Creek, Wood Chute Creek, and the North and South Forks of Quartz Creek for a considerable time after the ice had retreated from the rest of the quadrangle. The morainal forms are better preserved in these valleys, and the till appears slightly less weathered. The glacial deposits in the quadrangle are coextensive with those in the Basin quadrangle to the west, where Ruppel (1962) recognized only one period of glaciation; he considered the single period to be almost certainly contemporaneous with the "Early" glacial period in the Elkhorn Mountains, which was possibly early Wisconsin in age (Klepper, Weeks, and Ruppel, 1957).

RECENT DEPOSITS

The most recent deposits in the Jefferson City quadrangle are stream detritus and accumulations resulting from mass wastage (pl. 1). Almost all the streams have a narrow strip of alluvium along their entire course; in places the alluvium is difficult to distinguish from glacial outwash and colluvium. In the Boulder Valley a thin cover of Recent alluvium probably overlies Pleistocene and possibly late Tertiary alluvium. Several tributaries have deposited small alluvial fans along the Boulder River.

Three landslides have occurred in the vicinity of Rimini in the northwest corner of the quadrangle. Rhyolite of Tertiary age makes up the bulk of the material in each landslide. These slides were caused by oversteepening of the valley walls by glacial erosion. Sliding occurred after retreat of the ice. The rhyolite making up the large slide on the west side of Tenmile Creek was resting on a deeply weathered surface on which the movement took place. This slide probably dammed Tenmile Creek for a short time but not long enough for lake deposits to form upstream. The creek is still flowing a few hundred yards east of its former channel because of the debris fill.

A hummocky area in sec. 8, T. 7 N., R. 4 W., is probably a landslide or mudflow deposit. The bulk of the debris is volcanic rocks that crop out upslope to the west (pl. 1). This material probably slid over younger volcanic rocks, but, because of poor exposures, the geologic conditions that caused the landslide or mud flow could not be determined.

Most of the hill slopes in the Jefferson City quadrangle are covered by colluvium. Cover as much as 5 feet deep is common on hill slopes in the northeastern part of the quadrangle, where alaskite or silicified zones crop out along ridge crests. Many examples of deep colluvium can be observed at the tops of roadcuts along U.S. Highway 91.

Large talus deposits are common below outcrops of volcanic rocks but are uncommon below outcrops of granodiorite and quartz monzonite. The rhyolite on Red Mountain is considerably frost heaved, and the flanks of the mountain are covered entirely by blocky talus. Large talus deposits consisting of rhyolite blocks are common on Lava Mountain and the Spruce Hills, and talus consisting of blocks of volcanic rocks are conspicuous along Wood Chute Gulch.

ROCK UNITS

Rocks of the Boulder batholith, of Late Cretaceous or Paleocene age, underlie most of the Jefferson City quadrangle. Older rocks into which the batholith was intruded are exposed in a large roof remnant near the center of the quadrangle and in many smaller remnants. These older rocks are the welded tuffs and well-bedded sedimentary tuffs that constitute the upper two units of the Elkhorn Mountains volcanics of Late Cretaceous age (Klepper, Weeks, and Ruppel, 1957). Both units are cut by dikes of rhyodacite porphyry. Postbatholithic rocks of Tertiary age—the Lowland Creek volcanics (Oligocene) and equivalent intrusive quartz latite, and, in the northwestern part of the quadrangle, rhyolite that is considered younger than the Lowland Creek volcanics—were emplaced after a long period of erosion that exposed large areas of the batholith. The intrusive quartz latite occurs principally as steeply dipping, northeast-trending dikes in a north- and northeast-trending zone about 2½ miles wide.

Most of the rocks of the Boulder batholith within the quadrangle are believed to be part of a single pluton and are called the Butte quartz monzonite in this report. Batholithic rocks slightly younger than the Butte quartz monzonite include aplite, alaskite, and pegmatite—all of which have been mapped together simply as alaskite—and some granite porphyry. The alaskite occurs principally in steeply dipping dikes, but nearly horizontal dikes or sheets are not rare and there are a few small stocks in the northeast quarter of the quadrangle. Virtually all the alaskite is confined to the batholith or to prebatholithic rocks within a few hundred feet of the margin of the batholith. Rocks of uncertain composition in several small dikes are also referred to the late stage of the batholith.

The classification of igneous rocks—excluding alaskite, aplite, and pegmatite—used in this report (fig. 2) is slightly modified from Johannsen's classification (1939). With the exception of quartz monzonite and quartz latite, all rock names on figure 2 are those used by Johannsen.

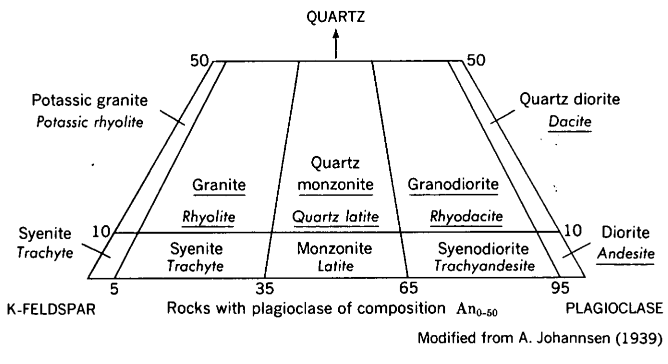

FIGURE 2.—Classification of igneous rocks used in this report. Names of aphanitic varieties are set in italics. Rock types referred to in this report are underlined.

ELKHORN MOUNTAINS VOLCANICS

The oldest rocks exposed in the Jefferson City quadrangle are the Elkhorn Mountains volcanics, into which the Boulder batholith was intruded. East and southeast of the quadrangle, the Elkhorn Mountains volcanics have been divided into three thick stratigraphic units (Klepper, Weeks and Ruppel, 1957) : a lower unit consisting predominantly of tuff, lapilli tuff, and tuff breccia; a middle unit of welded tuff and a few beds of nonwelded tuff; and an upper unit of well-bedded sedimentary tuff. In the Jefferson City quadrangle, only the middle and upper units are exposed. Here the middle unit consists largely of light greenish-gray welded tuffs and the upper unit of well-bedded dark-gray sedimentary tuffs. The contact between the two units is sharp—below the contact only welded tuffs have been recognized, and above it no welded tuffs have been recognized. East and south of the quadrangle, welded tuffs are interbedded with well-bedded tuffs and the contact is not as well defined. Many intrusive bodies of rhyodacite, most of which are too small to show on plate 1, cut both units. No lava flows have been recognized in the Elkhorn Mountains volcanics in the quadrangle.

The volcanic rocks form a large roof remnant near the center of the quadrangle and many smaller remnants. In the large remnant the middle unit is in contact with underlying rocks of the batholith, except for a distance of about 3 miles along the northwestern margin of the remnant, where the upper unit is at the contact. Most of the smaller remnants consist entirely of rocks of the middle unit. The distribution of roof remnants in the Jefferson City quadrangle and in adjacent quadrangles indicates that the contact between the volcanic rocks and the underlying rocks of the batholith is broadly horizontal or gently rolling; locally, however, the contact is nearly vertical.

The welded tuffs of the middle unit are predominantly light greenish gray to light gray and commonly contain crystals of feldspar and, rarely, biotite in an aphanitic groundmass. The most striking characteristic of these rocks is a crude, discontinuous banding caused by small, irregularly elongate lenses of dense, glassy-appearing material. For convenience of description, these lenses are referred to as wisps. They are roughly circular in the plane of the bedding and range from less than one-tenth of an inch to several inches in diameter. In detail, they are commonly irregular in outline and many are bent and draped around crystals and fragments of rocks. The wisps appear to have formed by collapse or squashing of hot, plastic, glassy fragments.

Thin sections of rocks from the Jefferson City quadrangle show that the welded tuffs are intensely recrystallized and slightly to intensely altered. In general, the rocks consist of slightly rounded crystals and angular fragments of plagioclase, potassium feldspar, biotite, and hornblende in a fine-grained matrix of potassium feldspar, plagioclase, and quartz, probably recrystallized from originally much finer grained material or glass. The groundmass in one specimen consists mostly of small crystals of cordierite heavily charged with almost submicroscopic inclusions. The plagioclase crystals in these rocks are mostly replaced by sericite; the potassium feldspar is partly replaced by clay minerals. Many of the wisps now consist entirely of anhedral quartz grains, and some contain both quartz and potassium feldspar grains. Less altered rocks of similar appearance in the Elkhorn Mountains east of the Jefferson City quadrangle are clearly welded tuffs of quartz latitic composition; they are described petrographically by Smedes (written communication, 1962).

The recrystallization and possibly much of the alteration of the welded tuffs are the result of contact metamorphism during the emplacement of the batholith. Although the alteration of plagioclase to sericite and potassium feldspar to clay minerals resembles hydrothermal alteration adjacent to veins in the area, the widespread and irregular distribution of the altered welded tuffs and the lack of any apparent spatial relations to known veins in many areas suggest a different cause for the alteration.

The upper unit of the Elkhorn Mountains volcanics consists dominantly of well-bedded dark-gray tuffs, but contains interbeds of massive fine-grained crystal tuff and lapilli tuff. In some beds of tuffaceous sandstone, the grains are well sorted and subrounded to rounded. Knopf (1913, p. 23) referred to these rocks as andesites. Chemical analyses of two samples from the Jefferson City quadrangle are given in table 1.

TABLE 1.—*Chemical analyses of Elkhorn Mountains volcanics*

[Analysts: H. F. Phillips, P. L. D. Elmore, K. E. White]

Specimen No.	2C108[1]	2C111[2]	3BC2[3]
Laboratory No.	52-2135CW	52-2136CW	53-2214-SC
SiO_2	57.2	62.8	62.8
Al_2O_3	13.3	16.8	18.3
Fe_2O_3	3.3	3.4	2.4
FeO	2.8	3.6	1.3
MgO	4.6	2.4	1.1
CaO	8.0	4.0	5.4
Na_2O	1.7	2.2	3.5
K_2O	2.4	2.4	3.3
TiO_2	.56	.82	.62
P_2O_5	.20	.27	.18
MnO	.11	.12	.08
H_2O	6.1	.74	.27
CO_2	----------	----------	.26

[1], [2] Tuff, collected by R. W. Chapman.
[3] Intrusive rhyodacite porphyry.

The upper and middle units of the Elkhorn Mountains volcanics are cut by intrusive bodies of rhyodacite porphyry similar to dikes, sills, and plugs of diorite porphyry in the Elkhorn Mountains east of the Jefferson City quadrangle (Klepper, Weeks, and Ruppel, 1957). Two irregular dikes in secs. 5 and 6, T. 7 N., R. 4 W., are shown on plate 1; many other small dikes, and probably some sills, occur in the roof remnant but have not been mapped separately.

The intrusive rhyodacite is a fine-grained dark-gray porphyritic rock consisting of small phenocrysts of plagioclase, biotite, and hornblende in a microcrystalline groundmass. The phenocrysts of plagioclase, usually andesine in composition, are twinned and usually are corroded by the groundmass. In some specimens the plagioclase is largely replaced by sericite. Hornblende phenocrysts are generally ragged and partly to almost completely replaced by biotite, magnetite, ilmenite, chlorite, epidote, or the groundmass. The groundmass is fine grained and xenomorphic and includes abundant plagioclase, lesser amounts of potassium feldspar and quartz, and accessory biotite, apatite, ilmenite, and sphene.

No fossils were found in the Elkhorn Mountains volcanics in the Jefferson City quadrangle, and thus no precise dating based on data from within the quadrangle was possible. However, Klepper, Weeks and Ruppel (1957) include descriptions by T. C. Yen, I. G. Sohn, R. E. Peck, J. B. Reeside, Jr., and R. W. Brown of several collections of fossils, principally plant remains, from the Elkhorn Mountains volcanics elsewhere. They conclude (p. 38):

> The paleontologic, stratigraphic, and structural evidence indicates to the authors that the Elkhorn Mountains volcanics are almost certainly wholly Cretaceous in age. But the evidence is insufficient to indicate whether they range in age from very late Niobrara or Telegraph Creek time to an upper limit that cannot be fixed more closely than Judith River time, or younger, or are restricted in age to Judith River time.

No fossils younger than Judith River (slightly older than middle Late Cretaceous) have been identified from the Elkhorn Mountain volcanics.

ROCKS OF THE BOULDER BATHOLITH

Rocks of the Boulder batholith, which underlie most of the Jefferson City quadrangle (pl. 1), have been separated into Butte quartz monzonite and late-stage batholithic rocks. In general, the Butte quartz monzonite is quartz monzonite and granodiorite, and the late-stage rocks are alaskite. Despite slight but mappable textural and compositional differences, all the rocks that constitute the Butte quartz monzonite, except possibly three fine-grained types, are considered part of a single large pluton. The differences are attributed to intermittent movement and to mixing between fractions of the magma that had reached different degrees of crystallinity near the contacts with overlying rocks. These differences are not common in the rocks that crystallized farther from the contacts.

BUTTE QUARTZ MONZONITE

The rocks making up the Butte quartz monzonite are mainly quartz monzonite but include some granodiorite (fig. 3). They range in composition from 20 to 48 percent plagioclase, 15 to 45 percent potassium feldspar, 15 to 40 percent quartz, less than 1 to 12 percent biotite, less than 1 to 8 percent hornblende, and less than 1 to 3 percent of magnetite, sphene, zircon, apatite, allanite(?), and rutile(?) combined. Pyroxene is scarce, but some rocks contain as much as 5 percent augite. Tourmaline is a common accessory mineral in one rock type. The average grain size of the minerals ranges from less than 1 mm to about 3 mm. Textures are commonly xenomorphic or hypautomorphic, equigranular or seriate; but many of the rocks are distinctly porphy-

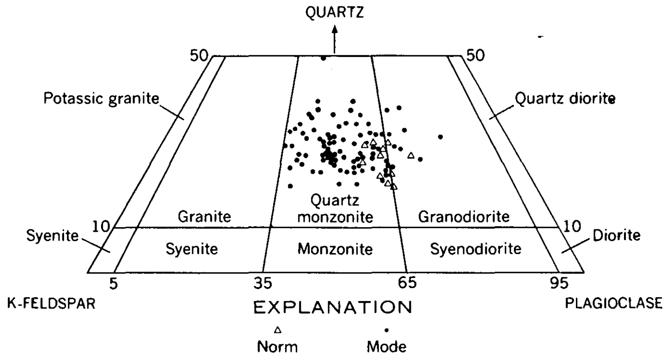

FIGURE 3.—Triangular diagram showing the proportions of modal and normative quartz, potassium feldspar, and plagioclase in Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

ritic, and some contain large potassium feldspar crystals as much as 3 cm long. The average specific gravity of rocks of the Butte quartz monzonite is between 2.60 and 2.70; the specific gravity of a few hand specimens is as high as 2.74.

The plagioclase ranges from thick tabular crystals to small irregular grains and is almost invariably zoned. Normal zoning is most common, but in some rocks oscillatory zoning is also common. Most of the crystals range in composition from rims of An_{20} to An_{40} to cores of An_{40} to An_{55}. Albite and Carlsbad twinning are common and pericline twinning is present locally. The large plagioclase crystals are generally euhedral against quartz and irregular against potassium feldspar. In some rocks they have thin albite rims adjacent to potassium feldspar grains, indicating replacement by the potassium feldspar. Near the cores of some crystals are small grains of potassium feldspar, magnetite, hornblende, biotite oriented parallel to the albite twins and numerous hairlike needles of rutile(?) oriented normal to the albite twins. Myrmekite is common along contacts of plagioclase and potassium feldspar. Slight sericitization of the plagioclase is common, and some crystals have intermediate zones that are completely replaced by sericite. Locally, plagioclase crystals have been partly altered to epidote.

The potassium feldspar ranges from small anhedral grains to large, anhedral to euhedral crystals. Microperthite is common, particularly in the large potassium feldspar crystals. In some of the porphyritic rocks, the potassium feldspar appears to have three habits: (1) early, interstitial, irregular grains that are only slightly microclinic or perthitic; (2) later, small anhedral grains that are dominantly microcline; and (3) late, large, anhedral to euhedral perthitic crystals. Much of the potassium feldspar appears to have replaced the earlier-formed minerals. Ragged inclusions of plagioclase, quartz, hornblende, and biotite are common.

Slight argillization makes all the potassium feldspar faintly cloudy.

The quartz is anhedral and usually has strain shadows. Some quartz grains contain many liquid inclusions and some have faintly detectable grid structure. Locally, the quartz appears to have replaced plagioclase and potassium feldspar or, in other places, to have been replaced by potassium feldspar.

Biotite, which is generally more abundant than hornblende, ranges from small ragged flakes to thick tabular grains. Most of the biotite is pleochroic; X, pale yellow to yellowish green; Y and Z, dark brown to dark greenish brown. The grains are usually partly altered to chlorite, clinozoisite, sphene, and magnetite. Some biotite crystals include minute crystals of zircon surrounded by thin pleochroic halos. In some of the rocks, small biotite crystals form sporadically distributed clusters with hornblende and magnetite. The biotite and magnetite in some of the clusters probably formed from the alteration of hornblende.

Hornblende typically forms ragged subhedral crystals, but corroded euhedral crystals are not uncommon in some of the rocks. The pleochroic colors are commonly X, yellow green; Y, light green; Z, dark green. Much of the hornblende is altered to epidote, chlorite, magnetite, and rarely clinozoisite and calcite.

Accessory minerals are sparse in most of the rocks and include euhedral apatite, anhedral to euhedral sphene, small crystals of zircon, magnetite, and rarely tourmaline. The accessory minerals are commonly spatially associated with biotite and hornblende.

Inclusions that can be definitely identified as specific prebatholithic rocks are extremely rare in the Butte quartz monzonite in the quadrangle; however, irregular masses that range from less than 1 inch to about 1 foot in diameter and consist largely of biotite, hornblende, plagioclase, and usually small amounts of potassium feldspar and quartz are common. These masses may be inclusions of earlier rocks that were thoroughly recrystallized and are now unrecognizable as to source. The masses do not appear to be concentrated near the remnants of prebatholithic volcanic rocks but are distributed randomly throughout most of the Butte quartz monzonite.

Mechanical disaggregation appears to be the dominant weathering process in the Butte quartz monzonite. In nonglaciated areas, the rocks commonly weather to large rounded outcrops surrounded by a soil-covered residual mantle, in which the mineral fragments are generally only slightly to moderately stained by iron oxide and even biotite is only slightly altered. Large amounts of grus accumulate rapidly at the base of outcrops of quartz monzonite in roadcuts in the nonglaciated areas (fig. 4). Weathering is more rapid along well-developed joints, and, as a result, the weathered outcrops typically have the appearance of piles of large, subrounded boulders (fig. 5). In glaciated areas, much of the weathered material has been removed, and many outcrops of quartz monzonite are surrounded by talus made up of relatively unaltered, slightly rounded boulders.

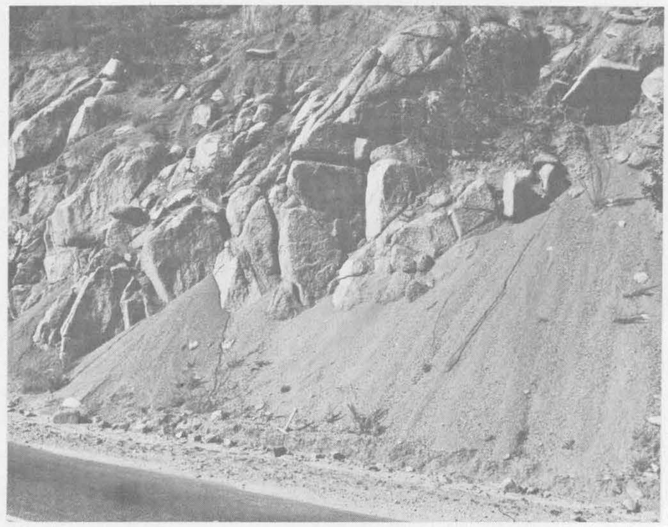

FIGURE 4.—An outcrop of quartz monzonite in a roadcut near the top of Boulder hill in sec. 35, T. 7 N., R. 4 W. The large amount of grus that has accumulated at the base of the outcrop is typically found in roadcuts in the nonglaciated part of the Jefferson City quadrangle.

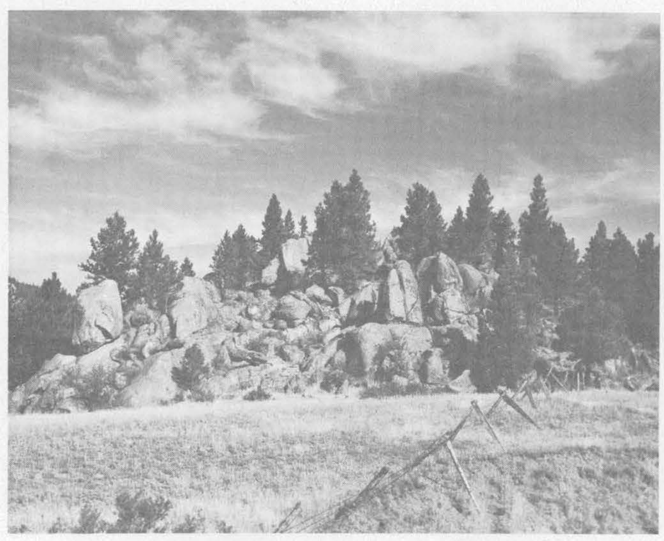

FIGURE 5.—A typical outcrop of nonglaciated Butte quartz monzonite. Weathering along joints gives the outcrop the appearance of large piles of subrounded boulders. The large boulders are deeply weathered.

TABLE 2.—*Chemical analyses, norms, and modes of Butte quartz monzonite*

[Analysts: H. F. Phillips, P. L. D. Elmore, and K. E. White; for location of specimens see pl. 1]

Specimen	3BC1	3BC4	3BC8	2C37	3BC6	3BC7	3BC14	3BC13	3B16a	3SR251b	3BC3	2C113a
Laboratory No.	53-2213-SC	53-2216-SC	53-2220-SC	52-2117CW	53-2218-SC	53-2219-SC	53-2226-SC	53-2225-SC	148620	148621	53-2215-SC	53-1867C
Field classification	cl	cla	ml	ml	ml	mla	md	mda	fl	flc	fd	fda
Chemical analyses												
SiO_2	63.8	64.6	70.8	71.2	71.1	70.9	64.3	63.5	68.8	68.8	67.3	68.0
Al_2O_3	15.9	15.5	15.5	15.4	15.3	14.4	14.8	15.4	14.8	16.2	14.9	15.6
Fe_2O_3	2.2	2.4	1.0	1.0	1.2	1.5	2.2	2.8	1.7	1.8	2.1	1.6
FeO	3.1	2.5	.93	.87	1.0	.68	3.0	2.4	2.0	.89	1.5	1.6
MgO	2.5	2.0	.76	.65	.72	.72	2.6	2.6	1.6	.74	1.6	1.2
CaO	4.2	4.0	2.4	2.4	2.1	2.3	4.1	4.4	2.9	3.3	2.9	3.2
Na_2O	3.0	3.1	4.2	4.2	3.8	3.4	2.9	3.0	2.7	3.1	2.9	3.1
K_2O	4.0	4.0	3.4	3.4	3.9	4.4	4.1	4.0	4.7	4.3	4.9	4.2
TiO_2	.59	.56	.21	.24	.23	.24	.62	.56	.42	.25	.51	.36
P_2O_5	.19	.19	.08	.10	.08	.08	.20	.22	.12	.14	.17	.16
MnO	.08	.10	.03	.04	.06	.08	.10	.10	.06	.08	.06	.12
H_2O	.62	.38	.26	.51	.68	.57	.63	.63	.59	.75	.57	.38
CO_2	<.05	<.05	.12	--	.18	.22	<.05	.19	<.05	.07	.31	--
Norms												
Quartz	18.0	19.9	27.4	27.4	28.9	28.6	18.7	18.7	26.6	26.6	24.0	25.4
Orthoclase	23.9	23.9	20.0	20.0	22.8	26.7	24.5	23.9	27.8	25.6	29.5	25.0
Albite	25.1	26.7	35.6	35.6	31.9	29.3	24.6	25.1	23.1	26.2	24.6	23.1
Anorthite	18.3	16.4	11.9	11.9	10.6	10.8	15.0	17.2	14.5	16.4	13.3	15.8
Corundum	--	--	--	.5	1.1	--	--	--	--	.5	--	.3
Diopside	2.0	2.3	--	--	--	--	3.1	3.7	--	--	.8	--
Hypersthene	8.0	5.9	2.4	2.3	2.2	1.8	7.1	5.6	5.6	1.8	3.9	3.9
Magnetite	3.2	3.5	1.4	1.4	1.9	1.6	3.2	4.2	2.5	2.6	3.0	2.3
Apatite	--	.3	--	--	--	--	--	.3	.3	--	.3	--
Ilmenite	1.2	1.1	.5	.5	.5	.5	1.2	1.2	.8	.5	.9	.8
Modes												
Quartz	20	18	32-33	26	31-30	28-28	21-23	19-15	33-33	--	29-21	29-20
K-feldspar	23	32	18-17	20	24-25	42-40	26-28	25-23	28-28	--	37-38	38-31
Plagioclase	44	35	45-45	48	41-37	25-26	40-37	42-46	32-28	--	27-30	22-40
Biotite	7	6	4-5	2	3-5	4-4	6-5	5-7	6-4	--	3-8	6-6
Hornblende	5	7	1-0	1	1-0	1-1	5-6	4-3	2-4	--	3-1	5-2
Pyroxene	<1	--	--	--	--	--	--	4-5	--	--	--	--
Accessory minerals	1	2	<1-1	<1	1-3	<1-1	1-2	1-1	<1	--	1-2	<1-1

TABLE 3.—*Quantitative spectrographic analyses of Butte quartz monzonite*

[Analyst: Janet D. Fletcher; for location of specimens see pl. 1]

Specimen	3BC1	3BC4	3BC8	3BC6	3BC7	3BC14	3BC13	3BC3
Field classification	cl	cla	ml	ml	mla	md	mda	fg
Cu	.004	.0004	.0006	.006	.001	.005	.005	.002
Ag	0	0	0	0	0	0	0	0
Pb	.0008	.0006	.0001	.0005	.002	.0006	.0006	.0008
Mn	.07	.06	.02	.03	.03	.05	.05	.04
Co	.001	.001	0	.0007	.0005	.001	.001	.0007
Ni	.002	.001	0	.0005	.0005	.002	.002	.002
Fe	1-5	1-5	1-5	1-5	1-5	1-5	1-5	1-5
Ga	.002	.001	.001	.001	.002	.001	.001	.001
Cr	.005	.004	.0006	.0004	.0004	.006	.005	.005
V	.01	.008	.003	.004	.003	.01	.01	.006
Sc	.002	.0009	.00008	.00009	.00006	.0005	.0008	.0003
Y	.003	.003	0	.0009	0	.005	.005	.002
Yb	.0003	.0003	0	.0002	0	.0002	.0002	.0002
La	.009	.008	0	0	.005	.008	.009	.008
Ti	.4	.3	.07	.1	.1	.4	.4	.2
Zr	.02	.01	.007	.01	.01	.02	.02	.009
Nb	0	0	0	0	0	0	0	0
Be	.001	.0009	.0005	.0008	.0005	.0009	.0009	.001
Mg	1-5	1-5	.2	.7	.4	.6	.7	.7
Ca	1-5	1-5	1-5	1-5	1-5	1-5	1-5	1-5
Sr	.2	.2	.2	.2	.2	.2	.2	.1
Ba	.1	.1	.2	.1	.1	.1	.1	.1
B	.001	0	0	0	0	.007	0	.001

Most of the rocks making up the Butte quartz monzonite fall within a narrow range in composition, as is illustrated by the chemical analyses, norms, and modes given in table 2 and the quantitative spectrographic analyses given in table 3. Because of this similarity in composition and because detectable lineation and foliation are sparse, other distinguishing features were sought that might lead to an understanding of the origin of the Boulder batholith. In 1953, Randolph W. Chapman,[1] who had been doing reconnaissance work on the batholith during the preceding two years, and Becraft set up a field classification for the Butte quartz monzonite based on slight differences in grain size, color, texture, and composition. The rocks were first divided into three main groups on the basis of grain size—coarse, medium, and fine. Each group was then subdivided into light-gray and dark-gray rocks, which were further subdivided on the basis of minor but diagnostic differences in texture and composition. The variations in grain size of typical light-gray rocks are illustrated in figure 6.

[1] Formerly with the U.S. Geological Survey and currently Chairman of the Department of Geology, Trinity College, Hartford, Conn.

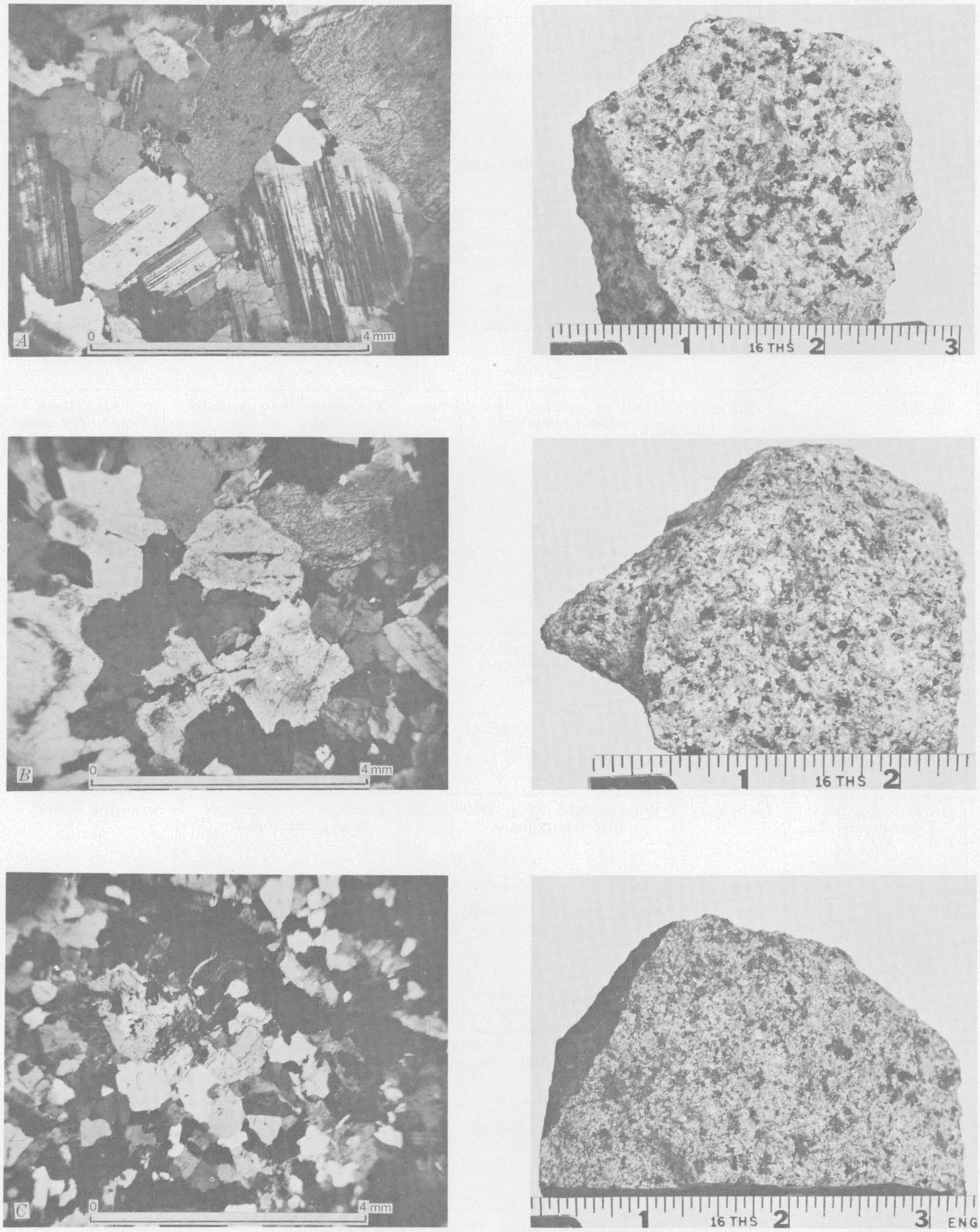

FIGURE 6.—Photographs and photomicrographs of typical specimens of light-gray Butte quartz monzonite, showing difference in grain size. *A*, Coarse-grained quartz monzonite (cl); *B*, medium-grained quartz monzonite (ml); *C*, fine-grained quartz monzonite (fl).

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TABLE 4.—*Petrographic data on*

Map symbol	Grain size (mm)	Color on fresh fracture	Diagnostic megascopic features	Texture	Plagioclase composition
cl	2.5–3	Light gray	Coarse grained; light gray	Hypautomorphic; locally porphyritic.	An_{20}–An_{50} Commonly zoned Ab rims common.
cla	2.5–3 (Phenocrysts range up to 3 cm long).	Light gray	Coarse grained; abundant large crystals of potassium feldspar.	Hypautomorphic; modified by anhedral to euhedral potassium feldspar crystals.	An_{30}–An_{50} Commonly zoned Ab rims common.
ml	1.5–2.5	Light gray	Medium grained; light gray	Xenomorphic to hypautomorphic; locally porphyritic.	An_{30}–An_{50} (Rare An_{20}) Commonly zoned Ab-rims common.
mla	1.5–2.5	Light gray	Medium grained; conspicuous reddish-brown tint.	Xenomorphic to hypautomorphic.	An_{25}–An_{50} (Rare An_{20}) Commonly zoned Ab rims rare.
md	1.5–2.5	Dark gray	Medium grained; dark gray	Hypautomorphic; locally porphyritic.	An_{40}–An_{53} zoned narrow An_{30}–An_{35} rims common.
mda	1.5	Dark gray	Relatively finer grained; contains dark gray commonly oriented plagioclase laths.	Hypautomorphic	An_{20}–An_{40} Zoned.
fl	1	Light gray	Fine grained; light gray	Hypautomorphic; porphyritic.	An_{35}–An_{58} Zoned.
fla	Groundmass, 0.5–1 Phenocrysts, 2.5.	Light gray	Fine grained; porphyritic with aplitic groundmass.	Porphyritic; xenomorphic groundmass.	An_{25}–An_{45} Zoned.
flb	1–1.5	Light gray	Fine grained; pinkish tint. Mafic minerals altered to chlorite and epidode.	Porphyritic; xenomorphic groundmass.	
flc	<1	Light gray	Fine grained; porphyritic with very fine grained almost aphanitic groundmass. Commonly contains large potassium feldspar and quartz crystals.	Porphyritic; xenomorphic groundmass.	An_{35}–An_{50} Zoned
fd	1–2	Dark gray	Fine grained; dark gray	Xenomorphic to hypautomorphic; commonly porphyritic.	An_{40}–An_{50} (Rare An_{30}) Slightly to strongly zoned.
fda	Groundmass, 1 Phenocrysts, 2.5 (Potassium feldspar crystals range up to 3 cm long).	Dark gray	Fine grained; large crystals of potassium feldspar common.	Porphyritic; modified by large potassium feldspar crystals.	An_{30}–An_{45} Few irregular An_{15}–An_{25} rims.

the Butte quartz monzonite

Modes, in percent											Accessory minerals	Specific gravity			Map symbol
Plagioclase		K-feldspar		Quartz		Biotite		Hornblende		Accessory minerals		Number of determinations	Average	Range	
Average	Range	Average	Range	Average	Range	Average	Range	Average	Range						
36	29–45	28	16–40	25	19–35	6	4–12	4	1–7	<1–2 Rare tourmaline.	Sphene, magnetite, zircon, apatite, allanite(?) rutile(?).	22	2.70	2.67–2.74	cl
32	25–35	30	23–35	27	18–35	5	2–8	5	2–7	<1–2	Sphene, magnetite, zircon, apatite, allanite(?) rutile(?).	11	2.69	2.66–2.73	cla
41	25–53	27	17–35	27	23–33	4	3–7	1	0–1	<1–3	Sphene, magnetite, zircon, apatite, allanite(?) rutile(?).	14	2.63	2.60–2.66	ml
31	23–37	38	30–47	24	19–30	3	2–5	3	0–7 Augite common, rarely as much as 2 percent.	Commonly <1, but rarely as much as 4 percent tourmaline.	Sphene, magnetite, zircon, apatite, allanite(?) rutile(?). tourmaline.	13	2.62	2.60–2.65	mla
39	35–44	24	18–18	23	20–19	7	4–10	7	6–8	<1–2	Sphene, magnetite, zircon, apatite, rutile (?) allanite(?).	11	2.70	2.67–2.73	md
44	42–46	24	23–25	17	15–19	6	5–7	2	1–3 (4–5 percent augite).	<1-1	Sphene, magnetite, zircon, apatite, rutile(?) allanite(?).	4	2.70	2.70–2.71	mda
32	26–40	28	20–36	31	22–42	5	4–6	3	1–6	<1	Sphene, magnetite, zircon, apatite, rutile(?) allanite(?).	11	2.67	2.65–2.70	fl
33	23–51	29	12–39	32	20–39	2–11 Dominantly biotite				<1–1.5	Sphene, magnetite, zircon, apatite, rutile(?) allanite(?).	17	2.64	2.60–2.71	fla
												4	2.63	2.62–2.64	flb
Not determined											Magnetite, apatite sphene, zircon.	4	2.60	2.60–2.61	flc
30	23–40	35	31–41	27	24–33	4	<1–9	3	1–7	<1–2 Rarely as 2 percent sphene.	Magnetite, apatite sphene, zircon, allanite.	10	2.66	2.63–2.69	fd
30	22-40	36	31–38	25	22–29	7	4–9	4	2–6	<1–1	Magnetite, apatite sphene, zircon.	9	2.66	2.64–2.68	fda

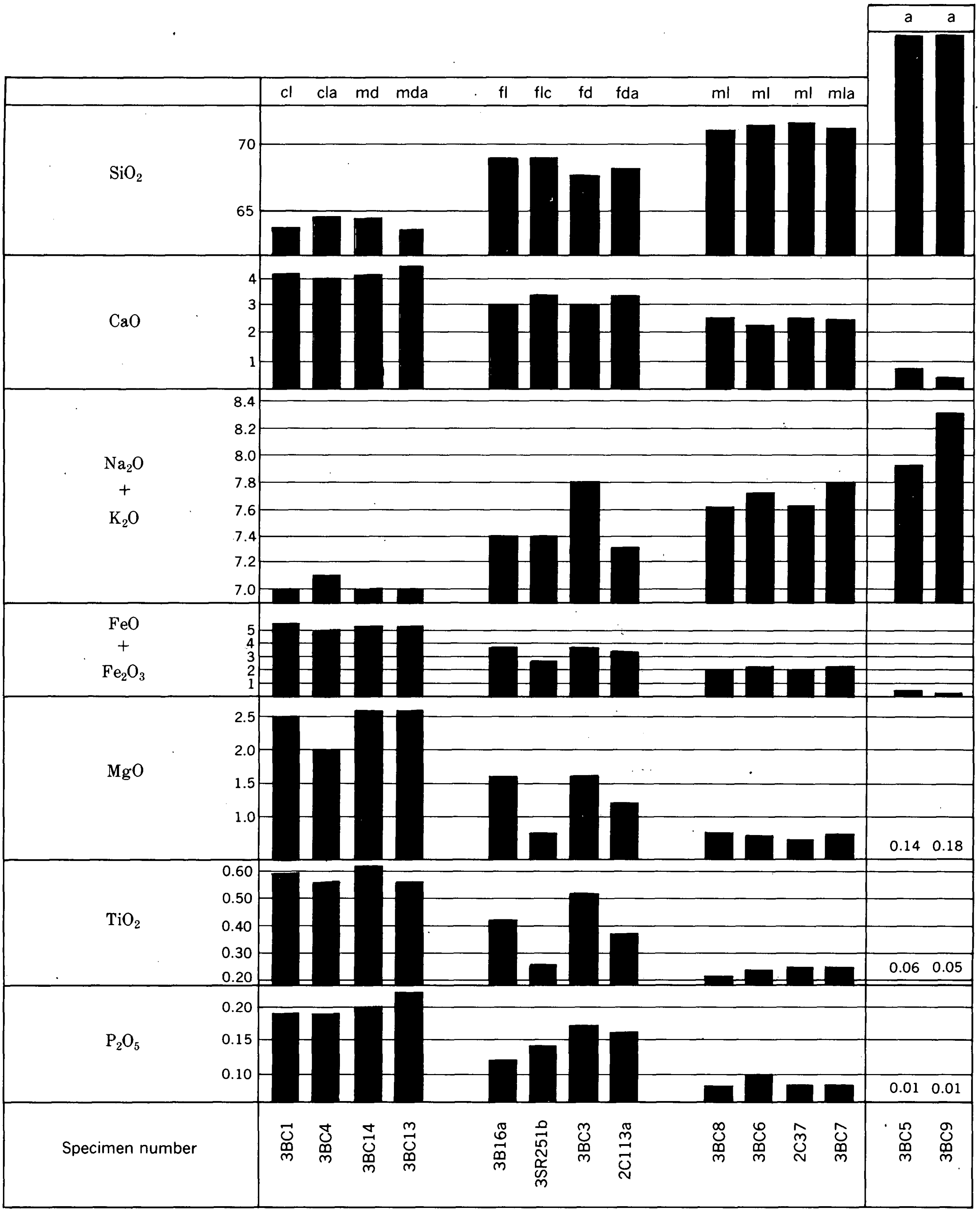


FIGURE 7.—Relations of oxides in rocks of the Boulder batholith. For location of specimens, see plate 4.

Using this classification, we have distinguished 12 mappable units of Butte quartz monzonite in the Jefferson City quadrangle (table 4), each of which is identified on the geologic map (pl. 1) by a symbol consisting of two or three letters. The first letter is c, m, or f, indicating that the rock is coarse, medium, or fine grained. The second letter is l or d, indicating that the rock is light gray or dark gray on a fresh fracture. A third letter—a, b, or c—is added where appropriate to indicate a rock type that can be mapped separately because of additional characteristic differences in texture and composition. Much of the Jefferson City quadrangle was mapped before the classification was devised, and therefore the symbol cm is used on the map in areas where medium- to coarse-grained rocks that range from light to dark gray were not subdivided. A specific symbol is shown within an area mapped as cm where the rock type is known but where contacts cannot be drawn because data are insufficient.

Our mapping of the Butte quartz monzonite in and south of the Jefferson City quadrangle and Ruppel's mapping (1963) west of the quadrangle have indicated that textural differences are common in the granitic rocks near the margin of the batholith, but that relatively uniform coarse- to medium-grained rocks predominate deeper within it. Most of the contacts between the different mappable units appear to be gradational, although few have been observed because exposures are poor. Commonly a contact between two rock types is sharp at one location and gradational over a considerable distance at another. These data suggest that all or most of the rock types making up the Butte quartz monzonite are parts of a single pluton, and that the textural variations resulted from considerable mixing, during emplacement and crystallization, between fractions of the magma that had reached different degrees of crystallinity.

Although they range only slightly in composition, the 12 units of Butte quartz monzonite in the quadrangle fall into three well-defined groups based on chemical composition. The coarse-grained rocks and the dark-gray medium-grained rocks make up one group; the light-gray medium-grained rocks are another group; and the fine-grained rocks are a third group, intermediate in composition between the other two (fig. 7). Only in the total alkali content of one rock, fd which is unusually high, is there any variation from this pattern in the 12 analyses of quartz monzonite from the quadrangle; chemical analyses of quartz monzonite from other parts of the batholith also fit the pattern (Ruppel, 1963; R. W. Chapman, written communication, 1956).

The reason for these relations is not clear. The three groups do not appear to represent three separate plutons; in fact, field relations do not support separation of the rock types into the three groups. For example, mla is gradational over a considerable distance into cl everywhere the two rock types are in contact, and mla is also gradational into fd along much of the contact between the two rock types; however, mla appears to have everywhere a sharp contact with ml. Similar relations are discussed later under individual rock types.

ROCK TYPE cl

The rock type cl is coarse-grained light-gray biotite-hornblende quartz monzonite and granodiorite. The rock is commonly hypautomorphic, equigranular or seriate with an average grain size of about 3 mm (fig. 6*A*), but it is locally modified by larger, irregular grains of potassium feldspar. The chemical analysis of cl given on table 2 is of a sample collected from a small mine dump along High Ore Creek about 1 mile north of the Boulder River (pl. 1). The computed norm of this analysis and also 19 modes of cl rocks calculated by the Larsen point-count method are shown on figure 8.

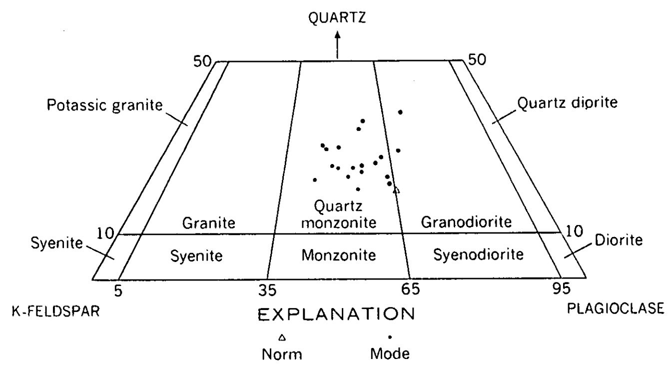


FIGURE 8.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type cl of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

In this figure, the total amount of plagioclase, quartz, and potassium feldspar was recomputed to 100 percent and plotted on a triangular diagram. The plots are well distributed throughout the area covered by the plots of all the types of Butte quartz monzonite shown on figure 3.

ROCK TYPE cla

The rock type cla is a coarse-grained light-gray biotite-hornblende quartz monzonite that has large, anhedral to euhedral crystals of potassium feldspar. It has been distinguished from cl on the basis of the large potassium feldspar crystals which are very abundant locally. The cla is gradational into cl and any contact drawn between them would be arbitrary. In the Jefferson City quadrangle, cla is largely restricted to the northeast corner and is well exposed in the quarry in sec. 8, T. 8 N., R. 3 W., about 1 mile west of Clancy along the Clancy Creek road. The cla analysis given on table 2 is of rock from this quarry.

The large crystals of potassium feldspar are generally as much as 3 cm long, and they contain many inclusions of plagioclase, quartz, biotite, and hornblende, which are commonly distributed randomly throughout the crystals but in some specimens are in zones near the edges of the crystals. This suggests that the large crystals formed late in the crystallization history of the rock, but because the large crystals are crudely alined at a few localities, they must have begun to grow while the rock was still mobile. Slight movement of the magma would produce the crude alinement, and later addition to the partly formed crystal might include earlier formed minerals.

ROCK TYPE ml

The rock type ml is medium-grained light-gray quartz monzonite and granodiorite (fig. 9). The ml is commonly equigranular and has an average grain size of 1.5 to 2 mm (fig. 6*B*). The ml south of Red Mountain has a slight greenish cast, but is similar chemically and mineralogically to other bodies of ml. About 1 mile south of Red Mountain the contact between ml and md is gradational over a width of a few hundred feet; about 2 miles farther south, the contact between ml and md is sharp or gradational over only a few feet. South of Lava Mountain ml has a sharp contact with cl, but 2 miles farther south the contact between cl and another body of ml appears to be gradational over a considerable width. The ml analysis labeled 3BC6 on table 2 is of a specimen from near the northeastern end of the ml body south of Red Mountain (pl. 1).

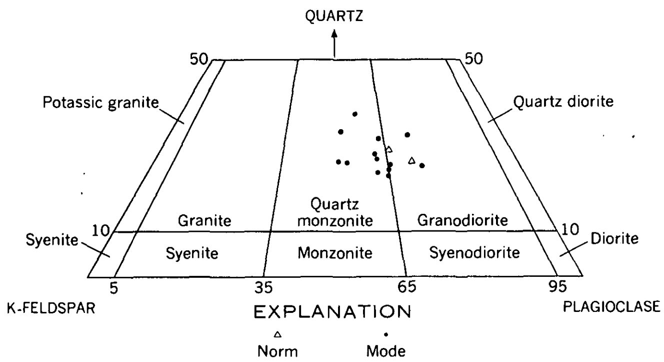


FIGURE 9.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type ml of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

The ml shown on plate 1 between Rowe Gulch and Lump Gulch and near the top of Boulder Hill in sec. 35, T. 7 N., R. 4 W., is slightly different from the other ml in the quadrangle. It is a light-gray biotite granodiorite. The rock consists of about 43 to 45 percent plagioclase, 16 to 18 percent potassium feldspar, 30 to 32 percent quartz, 4 to 5 percent biotite, and less than 1 percent hornblende. The plagioclase is lower in An content than the plagioclase in the other types of Butte quartz monzonite. It is normally zoned from An_{30} to An_{25}. The contacts between this ml and the surrounding rocks appear to be sharp but the actual contacts were not observed because of cover. The ml analysis labeled 3BC8 on table 2 is from an outcrop about 1 mile north of Rowe Gulch near the center of the ml body (pl. 1).

A considerable amount of ml was not mapped separately from other medium-grained and coarse-grained quartz monzonite and is included on plate 1 in the areas labeled with the general symbol Cm.

ROCK TYPE mla

The rock type mla is a medium-grained light-gray quartz monzonite (fig. 10) with a conspicuous reddish-brown tint. It is commonly equigranular with an average grain size of 1.5 to 2.5 mm. The mla usually contains slightly more potassium feldspar and slightly less plagioclase than ml. The rock very rarely contains augite—in one section as much as 2 percent. Several of the sections examined also contained tourmaline as an accessory mineral.

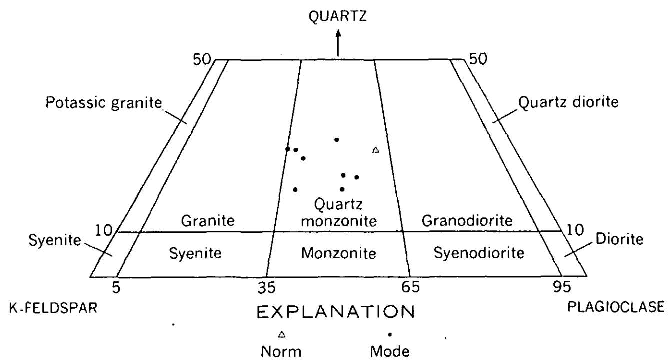


FIGURE 10.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type mla of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

The mla is exposed in two irregular bodies with a general northward trend on the east and west sides of Cataract Creek. The contacts between mla, cl, and fcl appear to be gradational over a considerable width, but the contacts between mla and ml appear to be relatively sharp.

The mla sample used for the analysis shown on table 2 was from an outcrop along the old road on the southwestern flank of Mount Thompson. Typical unweathered mla is also well exposed in the vicinity of the mine shaft in the northwest corner of sec. 21, T. 7 N., R. 5 W.

ROCK TYPE md

The rock type md is medium-grained dark-gray biotite-hornblende quartz monzonite and granodiorite (fig. 11). The rock is commonly equigranular or seriate, and the average grain size is 1.5 to 2 mm. The plagioclase is commonly a slightly darker shade of green than the plagioclase in cl or ml, probably the result of a slight higher average An content. The amount of hornblende is usually about equal to the amount of biotite in md; but in most of the other types of Butte quartz monzonite, biotite usually exceeds hornblende.

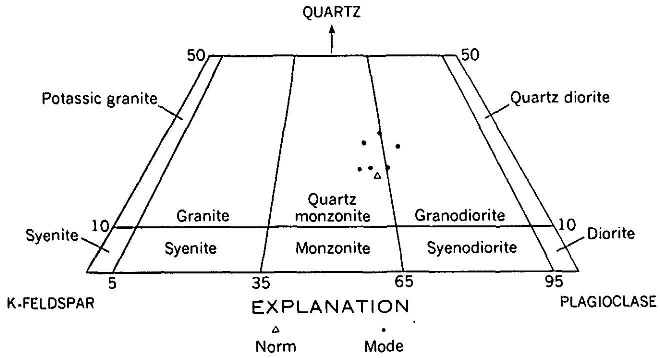


FIGURE 11.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type md of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

In the Jefferson City quadrangle, md is largely restricted to an area along the northwest boundary of the quadrangle. The md analysis given on table 2 is of rock from a large outcrop in the village of Rimini.

ROCK TYPE mda

The rock type mda is medium-grained quartz monzonite that is slightly finer grained than md and has dark-green commonly oriented plagioclase laths. The rock contains ragged, subhedral crystals of augite that are irregularly replaced by hornblende and magnetite. The augite makes up about 4 percent of the rock.

This rock type crops out in only one small area on the southwestern flank of Mount Thompson, and the chemical analysis of mda given on table 2 is of rock from this small mass. The relation of this rock to the surrounding mla and prebatholithic volcanic rocks is not clear because the contacts are covered, but the contacts appear to be sharp.

ROCK TYPE fl

The rock type fl is fine-grained light-gray porphyritic quartz monzonite that grades into granodiorite (fig. 12). The average grain size of the ground mass is slightly less than 1 mm (fig 6*C*), and some phenocrysts of plagioclase are as much as 5 mm long. Typical fl is exposed in the small body in the NW¼ sec. 35, T. 9 N., R. 5 W., near the road to Colorado Mountain lookout station, which is about a quarter mile north of the Jefferson City quadrangle. The fl analysis given on table 2 is of rock from this location. Some contacts between fl and other types of Butte quartz monzonite are sharp, but others are gradational over a considerable width.

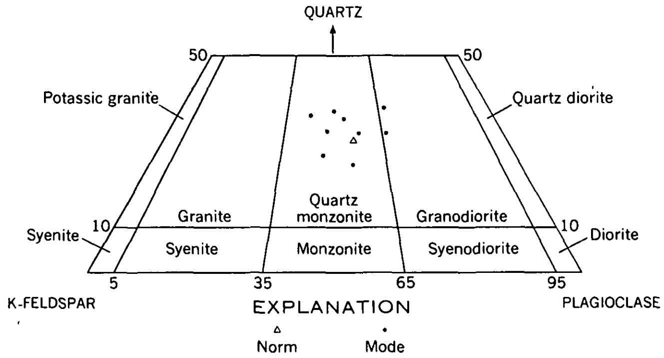


FIGURE 12.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type fl of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

The fl in the small mass exposed in sec. 22, T. 8 N, R. 4 W., is slightly different from the typical fl in the quadrangle, in that its texture is xenomorphic and slightly seriate, and because it contains an unusual amount of quartz—from 37 to 42 percent of the rock. Most of the mineral grains appear cataclastic. The relations of this rock to the surrounding rocks are not clear because all the contacts are covered, but the rock appears to be in sharp contact with the rock types cl and fla, and it is cut by dikes of alaskite.

ROCK TYPE fla

The rock type fla is fine-grained light-gray porphyritic quartz monzonite (fig. 13) with an aplitic groundmass. The phenocrysts are plagioclase, potassium feldspar, quartz, and biotite, in almost the same relative abundance as in most of the Butte quartz monzonite. The groundmass, which ranges from about 75 percent of the rock to less than 1 percent at the gradational boundaries between fla and the other rock types, is quite different from the other types of quartz mon-

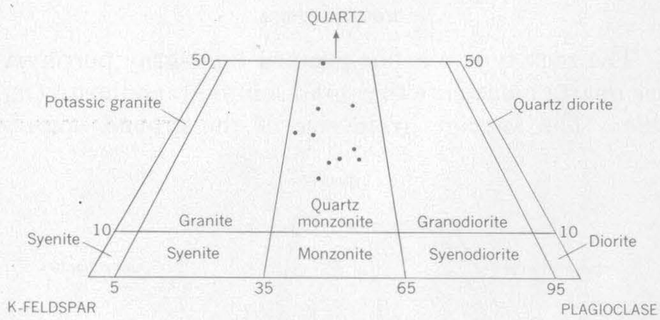


FIGURE 13.—Triangular diagram showing relative proportions of modal quartz, potassium feldspar, and plagioclase in rock type fla of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

zonite, approximating an aplite in both composition and texture (fig. 14). The groundmass consists largely of quartz and potassium feldspar and has a grain-size average of slightly less than 1 mm. Locally, small anhedral to subhedral plagioclase crystals (An_{15-25}) may make up as much as 15 to 20 percent of the rock. The

FIGURE 14.—Photomicrograph of sample of rock type fla showing replacement of a plagioclase phenocryst by quartz and potassium feldspar of the groundmass.

phenocrysts are considerably corroded and replaced by the groundmass. In some thin sections, three generations of potassium feldspar are present. The first generation appears to be largely orthoclase and occurs as partly replaced phenocrysts. The second generation, which appears to be largely microcline, is the potassium feldspar in the groundmass. Large crystals of microperthite that include fragments of earlier formed minerals make up the third generation of potassium feldspar. The plagioclase fragments in the microperthite crystals are surrounded by irregular but well-developed rims with markedly lower An content (fig. 15). Most

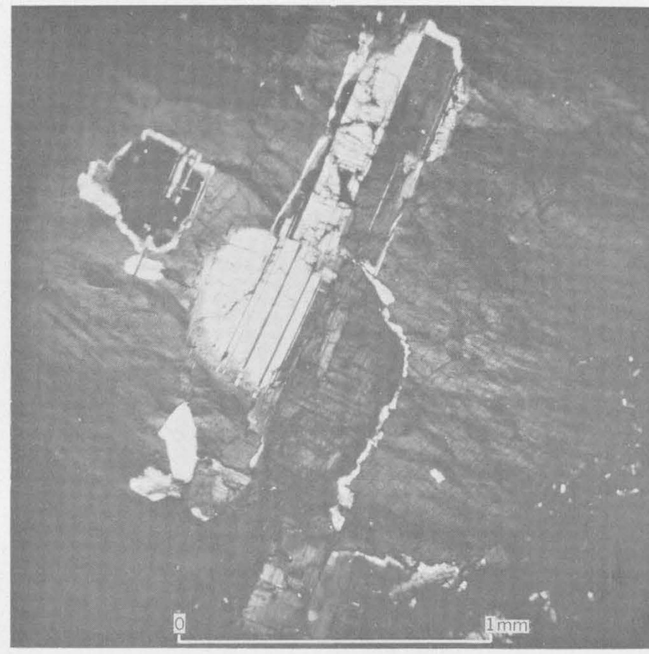


FIGURE 15.—Photomicrograph of sample of rock type fla showing the albitic rims around two plagioclase grains included in a large crystal of microperthite.

of the crystals are about An_{40} and the rims are about An_{25-30}.

The fla grades into cl, as illustrated in sec. 12, T. 8 N., R. 4 W., but has a sharp contact with the later alaskite.

ROCK TYPE flb

Rock type flb is a fine-grained quartz monzonite. It is light gray with a pinkish tint, and the mafic minerals are entirely altered to chlorite and epidote. The rock is porphyritic with corroded quartz and plagioclase phenocrysts in a very fine grained, xenomorphic groundmass of quartz, plagioclase, and potassium feldspar. The plagioclase phenocrysts have been almost entirely altered to sericite. The epidote is in small grains and may have been formed by alteration of pyroxene. The chlorite was probably largely formed by alteration of biotite. The only exposures of flb in the quadrangle are two small bodies in prebatholithic volcanic rocks in secs. 24 and 13, T. 7 N., R. 5 W. Its age relative to the other types of quartz monzonite is unknown.

ROCK TYPE flc

The rock type flc is a very fine grained light-gray porphyritic quartz monzonite modified by large potassium feldspar crystals. The phenocrysts are plagioclase, quartz, and rarely hornblende and biotite. Many plagioclase phenocrysts are slightly corroded by the groundmass, and most of the biotite is altered to chlorite. The groundmass is a sutured intergrowth of potassium feldspar and quartz, and probably some plagioclase. The large potassium feldspar crystals, commonly 3 cm long, include fragments of earlier formed minerals and appear to have formed very late in the crystallization of the rock. A few slightly coarser grained aggregates of quartz in the groundmass make the texture similar to some of the textures in the late-stage batholithic rocks. Possibly flc is a late-stage batholithic rock; at least it was produced very late in the intrusion of the main stage of the batholith. Only one very small body of flc has been mapped in the Jefferson City quadrangle. This is on the east side of Beavertown Creek in sec. 18, T. 7 N., R. 3 W. The analysis of flc on table 2 is of rock from this area. Another small body of this rock occurs west of Beavertown Creek, about in the center of sec. 13, T. 7 N., R. 4 W., but it was not mapped separately from the other quartz monzonite.

ROCK TYPE fd

Rock type fd is fine-grained dark-gray quartz monzonite (fig. 16). The rock is commonly porphyritic,

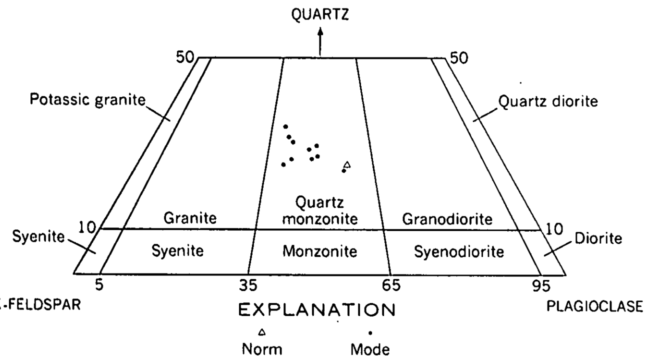


FIGURE 16.—Triangular diagrams showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type fd of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

and the average grain size is from 1 to 2 mm. Almost all of the fd in the quadrangle is at or near the present contacts of the batholith with the prebatholithic volcanic rocks. At the contacts with the volcanic rocks, the fd is very fine grained and in hand specimen closely resembles the recrystallized volcanic rocks. At increasing distances from these contacts, the fd is coarser grained and is gradational into underlying quartz monzonite. These relations suggest that fd is a chilled margin of the Butte quartz monzonite. However, the distribution of the fd is very local, and if it is a chilled margin of the batholith, it was not formed along most of the contact or was formed and later stoped away or replaced by coarser grained quartz monzonite. The analysis of fd given on table 2 is of rock near the contact with the overlying volcanic rocks on the ridge west of the Gray Eagle mine.

ROCK TYPE fda

The rock type fda is fine-grained dark-gray porphyritic quartz monzonite (fig. 17) that is characterized

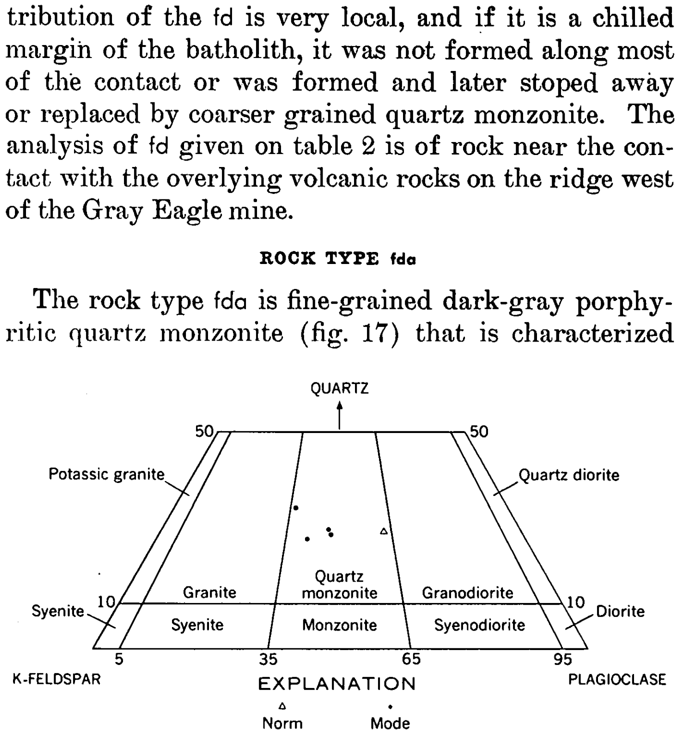


FIGURE 17.—Triangular diagram showing relative proportions of normative and modal quartz, potassium feldspar, and plagioclase in rock type fda of the Butte quartz monzonite. Feldspar and quartz recalculated to 100 percent.

by conspicuous euhedral potassium feldspar crystals, commonly as much as 3 cm long. The plagioclase phenocrysts range from 1 to 5 mm and generally have oscillatory zoning. Albite and Carlsbad twinning are common, and a few pericline twins are present. The potassium feldspar phenocrysts are twinned and enclose grains of plagioclase, quartz, biotite, and magnetite. The quartz phenocrysts are anhedral, strained, and partly replaced along boundaries by the groundmass. The groundmass is largely potassium feldspar and quartz with mutually interfering boundaries. Plagioclase rarely makes up as much as 10 to 15 percent of the groundmass. This rock is similar to fla except for the large potassium feldspar crystals. Another difference is the nature of the contacts—most of the fla contacts are gradational, and all of the fda contacts are sharp.

The fda is well exposed in two areas in the quadrangle. The largest area is between Corral Gulch and Buffalo Creek near the north boundary of the quadrangle, and the other area is along Clancy Creek about 6 miles west of Clancy. The rock is very well exposed in a recent roadcut in the NW¼ sec. 23, T. 8 N., R. 4 W. The analysis shown on table 2 is of rock from this roadcut.

LATE-STAGE ROCKS

A group of quartz-rich rocks including alaskite, alaskite porphyry, aplite, and pegmatite intruded the Butte quartz monzonite and prebatholithic volcanic rocks within a few hundred feet of the batholith. These rocks, which are designated alaskite on plate 1, together with granite porphyry that occurs near the Mt. Washington mine and in the southeast corner of the Jefferson City quadrangle, and a few fine-grained, porphyritic dike rocks of diverse composition, make up the late-stage rocks of the batholith in this area. Alaskite is by far the dominant late-stage rock. Age relations among these three rock types are not known because the rocks were not observed in contact.

ALASKITE

Alaskite—which in this report includes alaskite porphyry, aplite, and pegmatite as well as alaskite—occurs principally as dikes; however, a few large, irregular bodies have been recognized. All the quartz-rich rock types may be present in a single outcrop, but more commonly only one or two are present. They are usually irregularly distributed in the dikes or intrusive bodies; the coarser grained rocks are not restricted to the centers, nor are selvages of finer grained rock characteristic of the margins. Many pegmatite dikes have milky quartz cores that locally make up most of the dike. A few large milky quartz masses, which have been mapped separately (pl. 1), are genetically related to the alaskite. Near the margins of three quartz masses, large potassium feldspar phenocrysts are intergrown with the quartz. At the southern margin of the quartz mass, south of the Boulder River in sec. 16, T. 6 N., R. 5 W., the quartz is gradational into a coarse-grained pegmatite. The quartz mass in sec. 5, T. 8 N., R. 4 W., is gradational into pegmatite and also alaskite.

In the Jefferson City quadrangle, the contacts between most of the alaskite and Butte quartz monzonite are sharp, but a few contacts are gradational over several inches. The large alaskite body between Clancy Creek and Westover Gulch (pl. 1) is cut by many finer grained alaskite and pegmatite dikes with gradational margins.

The alaskite does not weather as rapidly as the quartz monzonite and thus typically crops out along ridge crests and elsewhere forms low ridges and benches. Commonly the slopes below alaskite outcrops are covered by alaskite float to a depth of several feet. This is well illustrated along a bulldozed road in sec. 17, T. 8 N., R. 3 W.

Many of the alaskite dikes appear to have been intruded along poorly developed joints. Commonly a dike follows one joint for a short distance and then a differently oriented joint. A single dike may have several different attitudes. For example, in the Free Enterprise mine two nearly horizontal dikes are connected by a steeply dipping dike; all three are probably part of the same intrusion and could be considered as one dike. Similar relations between alaskite dikes can be observed in many roadcuts between Butte and Helena.

Alaskite is abundant only in a northeast-trending belt that extends across the eastern part of the Jefferson City quadrangle; it is relatively uncommon in the western part. The actual contacts of the batholith with overlying rocks do not appear to have been important loci for emplacement of alaskite dikes. Relatively little alaskite occurs near the eastern margin of the batholith, and alaskite is not common at the contact between the batholith and the large roof remnant of Elkhorn Mountains volcanics, except along its eastern margin.

Most of the following information on mineralogy, composition, and structures and textures of the alaskite is from George J. Neuerburg (written communication, 1954).

MINERALOGY

The alaskite consists of quartz (usually about one-third of the rock); potassium feldspar (generally from ⅓ to ½ of the rock); plagioclase (sodic oligoclase to albite), locally altered to dickite or kaolinite; biotite (commonly less than 1 percent); trace amounts of zircon, apatite, hematite, magnetite, and pyrite; and very sparse molybdenite and chalcopyrite. Tourmaline is locally abundant. The secondary minerals are dickite or kaolinite, rutile, illite, chlorite, limonite, hematite, leucoxene, and epidote.

Quartz.—Quartz occurs as anhedral to subhedral grains in alaskite with xenomorphic texture, as granophyric intergrowths with feldspar, and as the cores of many pegmatites. Deformation is illustrated by strain shadows, generally slight except in the vicinity of zones of cataclasis, and by optic angles of 5° to 10°. Trains of liquid inclusions similar to those described by Tuttle (1949) are common but not abundant. A faint grid structure, resembling the grid twinning of microcline, is common and is most easily observed in sections nearly perpendicular to the *c*-axis.

Potassium feldspar.—Potassium feldspar occurs as anhedral grains that commonly show a vaguely tabular outline, and as larger, commonly rectangular crystals that are irregularly distributed throughout much of the alaskite and are an essential part of all pegmatites and graphic-textured rocks. Anhedral inclusions of quartz and plagioclase are common in the larger crystals. Much of the potassium feldspar has small, irregular areas of grid twinning that make up only a small part of individual grains. The usual spectacular grid twinning of microcline is uncommon; where it is present (generally in the larger crystals) it passes into areas of undulose extinction and into areas of even extinction with no apparent twinning. A few crystals in each slide, principally the tabular grains, show Carlsbad twinning.

Almost all specimens contain small amounts of perthite. The commonest form is microscopic or nearly microscopic vein perthite, generally making up less than one percent of the feldspar. Patch-shaped areas of perthite are less common. Both vein and patch perthite are coarser and more abundant in the larger crystals.

Alteration of potassium feldspar is generally very slight. The products are scattered specks and minute grains of sericite, and, in all specimens, submicroscopic grains of clay that show a slight tendency toward concentration along cleavage separations and along perthite boundaries.

Plagioclase.—Plagioclase has three common habits in most of the alaskite. Some occurs as anhedral grains showing faint normal zoning. More commonly, it occurs as small, thick, tabular, subhedral crystals, mostly along potassium feldspar grain boundaries. It also occurs in perthite. The plagioclase is most commonly 10 to 25 percent anorthite, but crystals of different habits have different compositions, and, because the plagioclase is generally zoned, the composition ranges widely within single grains as well as from grain to grain within a single slide. The small grains along potassium feldspar boundaries are more calcic than the average composition of the anhedral, zoned crystals; however, the anhedral, zoned crystals commonly have cores that are more calcic than the other plagioclase in the alaskite. Twinning is largely after the albite law, and almost exclusively so in perthite and in the small crystals along microcline grain boundaries. Carlsbad twinning, uncommon in the perthite, is almost always present in the anhedral, zoned grains; pericline twinning is scarce in crystals of these two habits.

Plagioclase is altered in several ways. The cores are commonly partly altered to a fine-grained mixture of sericite, zoisite, albite, and clay. Outside the cores, sericite is localized along cracks. In places, albite irregularly replaces the earlier, more calcic plagioclase, principally along cleavage cracks. These alterations generally amount to less than 1 percent of the plagioclase crystals.

Plagioclase in a few dikes of alaskite is altered to a fine-grained mosaic of about equal proportions of dickite and kaolinite, which very rarely contain small relics of the plagioclase. In places the alteration is related to hydrothermally altered zones cutting the quartz monzonite wallrock and the alaskite. In other places the alteration occurs in irregular, poorly defined areas with no apparent control except that it is slightly more common in pegmatites; but alteration may be entirely lacking in some pegmatites within one intrusive body. In one stock, north of Boulder, the dickite and kaolinite alteration extends into the surrounding Butte quartz monzonite. The dickite and kaolinite alteration is everywhere associated with the alteration of biotite to illite and rutile.

Intergrowths of quartz with dickite and kaolinite are common (figs. 18 and 19). No evidence of replacement of potassium feldspar by dickite and kaolinite was observed.

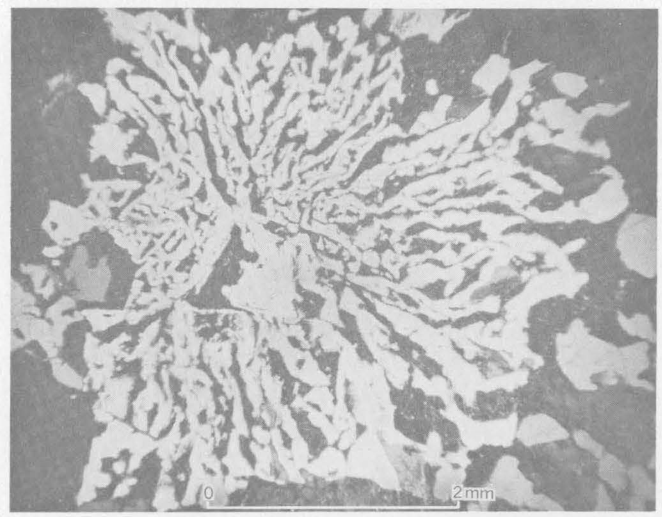


FIGURE 18.—Photomicrograph of alaskite showing cauliflowerlike rosette of granophyric quartz in dickite and kaolinite.

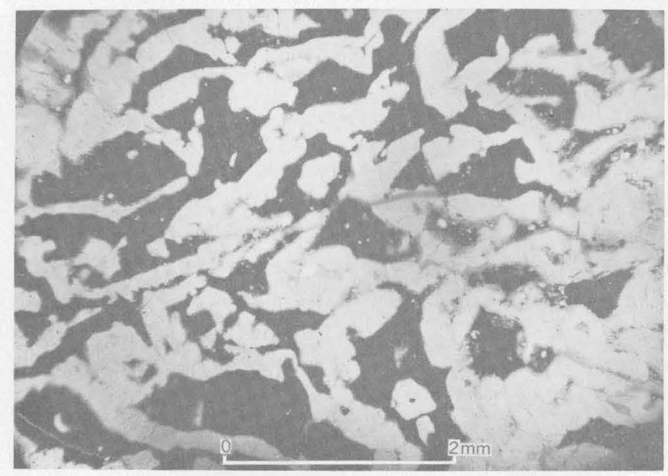


FIGURE 19.—Photomicrograph of alaskite showing intergrowth of quartz with dickite and kaolinite. Note the bulbous outlines of the joined quartz members and the thin gray selvages of quartz and dickite and kaolinite around many of the quartz members.

Biotite.—Small, tabular grains (0.1–0.2 mm) of biotite are common in the alaskite, but very rarely make up as much as one percent of the rock. The pleochroism is from light yellow (X) to brown and greenish brown (Y, Z). Much of the biotite is altered to illite, muscovite, and rutile. Illite—in these rocks a fine-grained micaceous mineral of low positive relief and low birefringence—in a few specimens grades by increase of relief and birefringence into muscovite. Illite commonly contains minute dark granules of rutile and leucoxene; muscovite occasionally contains larger rutile grains. Alteration of biotite to penninite with minute granules of clinozoisite, epidote, and sphene has occurred sparsely in alaskite.

Tourmaline.—Tourmaline is most common in pegmatite, but it also occurs in alaskite and aplite. In pegmatite, the tourmaline usually forms small, space-filling aggregates or graphic intergrowths with quartz. The peripheral parts of these tourmaline groups consist of small stringers and grains with a common orientation along grain boundaries of quartz and feldspars.

The pleochroism is E, light yellowish rose, and O, very dark olive green to black. Many crystals, most of which are sievelike grains, are partly rimmed by very small prisms of indigo-blue tourmaline, which are in optical continuity with the larger crystals. The tourmaline is jet black in hand specimen.

Other minerals.—Minor accessory minerals are scarce in these rocks. Most specimens contain small amounts of magnetite. A few isolated crystals of apatite and zircon with magnetite are spatially related to biotite. Small cubes of pyrite are sparse. Molybdenite occurs very rarely along cracks in aplite. Rutile is present as colorless hairlike needles in biotite, quartz, and feldspar, and as small dark-golden-yellow to very dark reddish brown grains and prisms. The larger grains are in altered biotite, along grain boundaries, and in small veinlets.

COMPOSITION

Modal analyses of 42 thin sections ranging from aplite to pegmatite indicate a considerable variation in composition (fig. 20). The amount of quartz in the analyses ranges from 31 to 42 percent, but could have been extended to 100 percent by choice of sections from quartz cores of pegmatites. Plagioclase ranges from about 1 percent to 35 percent and potassium feldspar from 30 to 65 percent.

The two chemical analyses of alaskite from the Jefferson City quadrangle (table 6) and several analyses of the rock from nearby areas suggest a much smaller range in composition than do the modal analyses. One of the chemical analyses (3BC5) is of rock from a relatively large intrusive mass of alaskite that ranges only slightly in texture. The other analysis (3BC9) is of rock from a small dike that consists of alaskite, pegmatite, aplite and graphic granite; the sample was carefully selected to retain about the same relative proportions of each rock type.

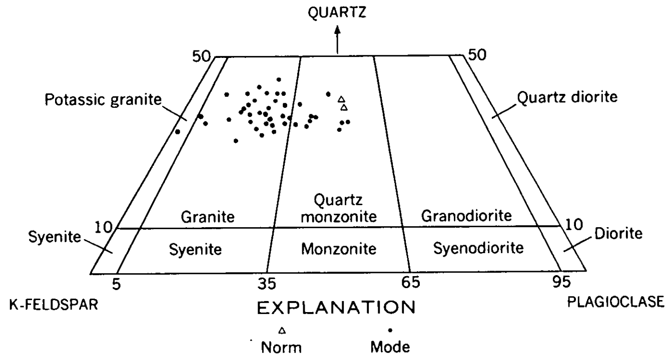


FIGURE 20.—Triangular diagram showing the proportions of modal and normative quartz, potassium feldspar, and plagioclase in alaskite. Feldspar and quartz recalculated to 100 percent.

Spectrographic analyses of quartz from two of the large quartz masses, believed to be cores of pegmatites, are given on table 7, along with spectrographic analyses of the two alaskite samples that were analyzed chemically. The metal content of the quartz specimens is very low. Larger samples might contain slightly more copper, molybdenum, and iron than the analyzed samples because very sparse grains of pyrite, molybdenite, and chalcopyrite were observed in some quartz masses.

TABLE 5.—*Chemical analyses and norms of alaskite*

[Analysts: H. F. Phillips, P. L. D. Elmore, K. E. White; for location of specimens see pl. 1]

Specimen No.	3BC5	3BC9
Laboratory No.	53-2217-SC	53-2221-SC
Chemical analyses		
SiO_2	77.8	77.9
Al_2O_3	12.9	12.7
Fe_2O_3	.35	.34
FeO	.17	.15
MgO	.14	.18
CaO	.68	.37
Na_2O	3.1	3.5
K_2O	4.8	4.8
TiO_2	.06	.05
P_2O_5	.01	.01
MnO	.01	.01
H_2O	.20	.14
Norms		
Quartz	40.0	38.4
Orthoclase	28.4	28.4
Albite	26.2	29.3
Anorthite	3.6	1.7
Corundum	.9	1.2
Hypersthene	.3	.4
Magnetite	.5	.5

TABLE 6.—*Quantitative spectrographic analyses of alaskite and semiquantitative spectrographic analyses of quartz from two large quartz masses*

[For location of specimen, see pl. 1]

Specimen	3BC5 [1]	3BC9 [1]	5B206a [2]	3SR145 [2]
Cu	0.001	0.0002	0.002 –0.005	0.002 –0.005
Pb	.0006	.0005	----	----
Mn	.003	.003	.01 –0.021	.01 –0.021
Fe	.4	.2	1.2 –2.5	1.2 –2.5
Ga	.001	.001	----	----
Cr	.0002	.0003	.0005–0.001	.0005–0.001
V	.0008	0	----	----
Y	0	.001	----	----
Yb	0	.0003	----	----
Ti	.05	.03	.002 –0.005	.002 –0.005
Zr	.006	.02	----	----
Be	.001	.0009	----	----
Mg	.04	.01	.001 –0.0021	.001 –0.0021
Ca	.9	.2	.01 –0.021	.01 –0.021
Sr	.04	.004	----	----
Ba	.02	.0009	----	----
B	0	.001	.01 –0.021	.01 –0.021
Si	Not reported	----	>10	>10
Al	----	----	.02 –0.05	.02 –0.05
Ni	0	0	.001 –0.0021	.001 –0.0021
Ag	0	0	.0001–0.0002	0

[1] Alaskite; analyst, Janet D. Fletcher.
[2] Quartz; analyst, Charles S. Annell.

TEXTURES

The alaskite in a single dike or irregular body generally has several textures; some of them visible in hand specimen, others visible only under the microscope. The most common texture is fine- to medium-grained xenomorphic, consisting principally of a mosaic of quartz and potassium feldspar—nonperthitic to slightly perthitic—with some zoned plagioclase crystals and scattered small crystals of biotite. The grain size ranges from 0.5 mm to 2 mm but is most common about 1 mm. The average grain size of the xenomorphic texture differs even within the same outcrop; these differences do not seem to be related, either to any discernible structure, or to any difference in mineralogy.

A second texture is produced by cauliflowerlike rosettes of quartz in a xenomorphic texture (figs. 21 and 22). Commonly the quartz is confined to a single potassium feldspar crystal, but in many thin sections it transects more than one grain of potassium feldspar as well as grains of plagioclase and quartz. In some rock specimens only one or two rosettes of quartz are present; in others they are numerous. The rosettes are usually larger than the grains of the enclosing rock—averaging about 1.5 mm. They occur irregularly throughout single intrusives and are not related to any apparent structure.

The several pegmatitic textures in the alaskite have many fabric features in common, but their structural relations differ greatly from one intrusive to another and even within the same intrusive. The textures are: (1) Coarse graphic intergrowths of quartz and potassium feldspar, with irregular quartz glyphs unlike the classic texture of graphic granite in shape but like it in crystallographic orientation; (2) coarse xenomorphic intergrowths of quartz and feldspar grains averaging about 1 inch in size; and (3) isolated large potassium feldspar crystals (fig. 23), locally graphic.

Discontinuous tabular lenses of xenomorphic pegmatite are common parallel to the walls of thin alaskite dikes. These lenses are commonly associated with graphic granite, and many of them contain small

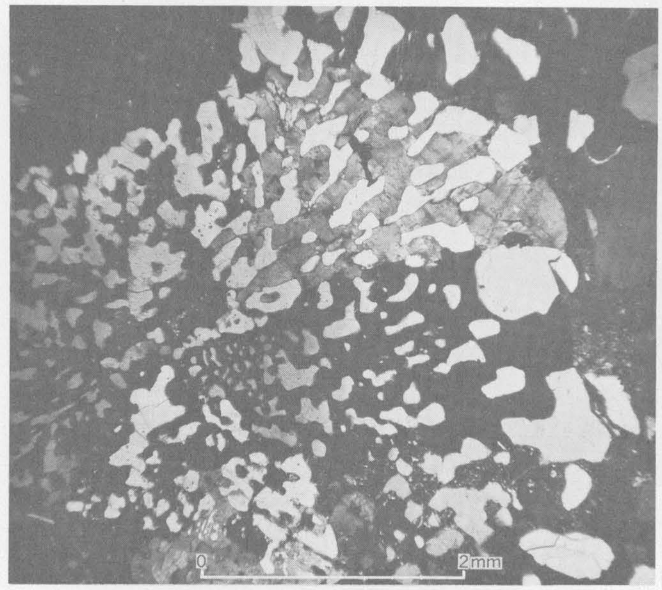


FIGURE 21.—Photomicrograph of a large quartz rosette in alaskite overprinting several crystals of potassium feldspar and altered plagioclase. Compare the shapes of the quartz glyphs in this figure with those in figure 22.

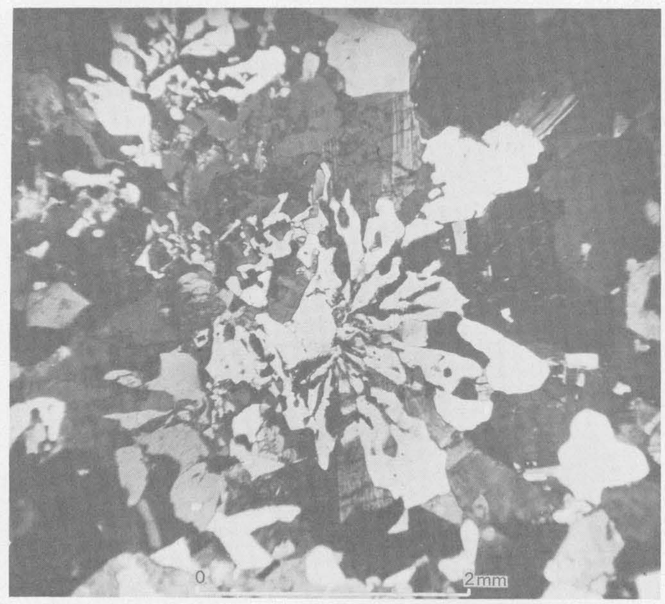


FIGURE 22.—Photomicrograph of a radiating quartz rosette in alaskite cutting earlier feldspar crystals. Note the increase in size of the quartz members outward from the center of the rosette.

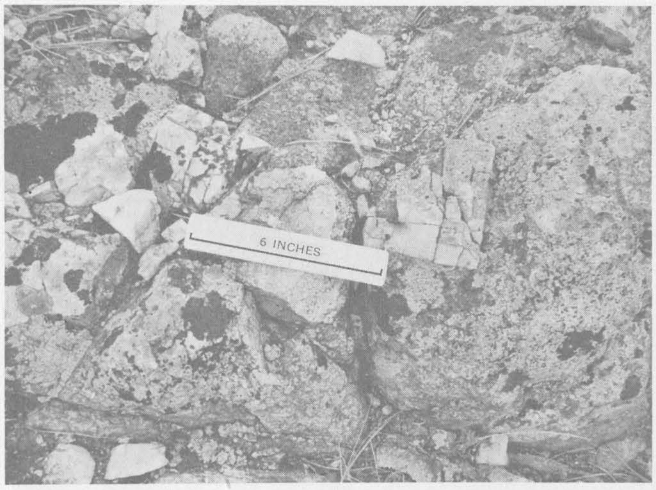


FIGURE 23.—Large potassium feldspar and quartz crystals in a small dike of medium-grained alaskite in sec. 24, T. 8 N., R. 4 W.

tourmaline crystals. In a stock north of Boulder, thin dikes of pegmatite that cut the alaskite near one wall are later than the cauliflowerlike rosettes of quartz.

The pegmatite occurs most commonly as small irregular masses in finer grained alaskite and aplite. These pegmatite masses range considerably in grain size (2–10 mm), diameter (0.5–5 cm), shape, and abundance. Some have sharp boundaries and contrast markedly in grain size with the surrounding rock (fig. 24); others grade into it (fig. 25). Some pegmatites are zoned,

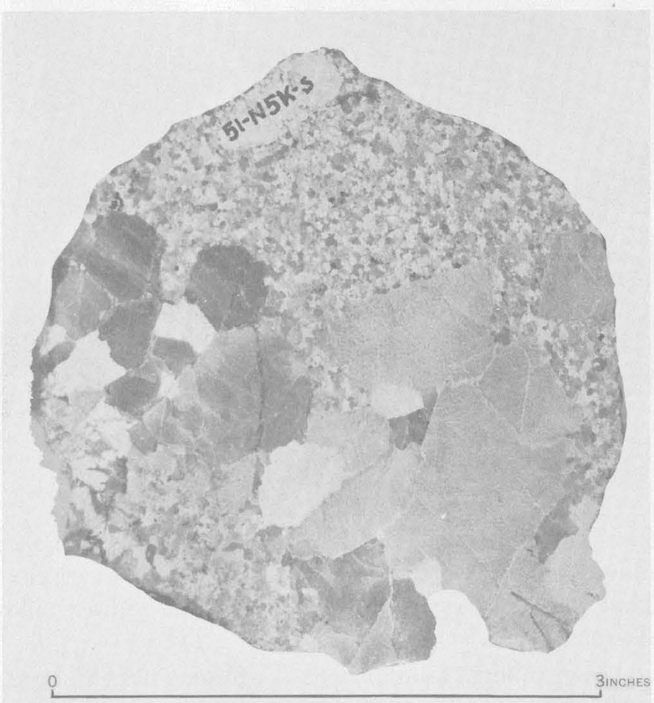


FIGURE 24.—Pegmatitic mass in medium-grained alaskite. Note the sharp contact between the pegmatite and alaskite.

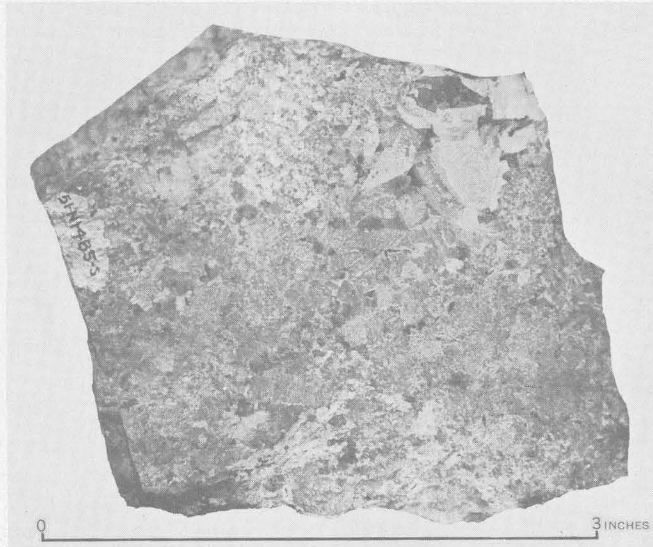


FIGURE 25.—Pegmatitic mass in alaskite. Note the indefinite contact between the pegmatite and alaskite.

both texturally and mineralogically. The most common zonal structure is a core of quartz surrounded by pegmatite, which in turn is surrounded by graphic granite. The core commonly contains tourmaline and in places is miarolitic. Locally the zones may be reversed. All the pegmatites usually contain more perthite and less plagioclase than the surrounding finer grained alaskite or aplite.

GRANITE PORPHYRY

Granite porphyry is exposed in two small areas in the Jefferson City quadrangle—one in sec. 17, T. 7 N., R. 4 W., near the center of the large roof remnant of Elkhorn Mountains volcanics, and one in the extreme southeast corner of the quadrangle extending southward into the Boulder quadrangle. The outcrops are poor, and thus the relations between the granite porphyry and the surrounding rocks are not known. The age of the granite porphyry is uncertain, but the composition of the rock appears to resemble the alaskite more closely than it does the Butte quartz monzonite, and thus it has been included in the late-stage batholithic rocks.

The granite porphyry in sec. 17 is light brownish gray and its average grain size is between about 1 mm and 3 mm. The rock is only slightly porphyritic with sparse phenocrysts of quartz and potassium feldspar; it consists largely of quartz and potassium feldspar with a small amount of plagioclase and chlorite. The quartz is anhedral and all grains show strain shadows. All potassium feldspar crystals include granophyric intergrowths of quartz and potassium feldspar, which are best developed around the rims of the individual crystals, particularly where they are in contact with quartz grains. All the potassium feldspar is slightly cloudy as the result of clay alteration. Most of the plagioclase grains also appear to have been largely replaced by granophyric intergrowths of quartz and potassium feldspar. The remaining ragged crystals are largely replaced by sericite, and thus albite twinning is extremely vague. Chlorite appears to have been formed largely by alteration of biotite. The original rock may have been a leuco quartz monzonite that underwent cataclasis, permitting deuteric solutions to replace crushed grain boundaries with the granophyric intergrowth.

DIKE ROCKS

The Butte quartz monzonite is cut by many small dikes of diverse composition. The rocks are fine grained and porphyritic. Some are intensely altered and others are so deeply weathered that their original compositions cannot be determined. Some of these rocks occur only in a single dike, but others occur in several dikes at different localities in the quadrangle.

Dikes of porphyritic rocks with rounded quartz phenocrysts and euhedral feldspar phenocrysts occur in secs. 26 and 35, T. 8 N., R. 5 W. The dikes are 3 to 15 feet wide and as much as 1,500 feet long. They appear to dip steeply, and the outcrops are generally low, rubbly, and thoroughly stained by iron oxide. The groundmass is a microcrystalline aggregate of quartz, albite, potassium feldspar, sericite, calcite, pyrite, magnetite, and leucoxene. Quartz phenocrysts, commonly 10 mm in diameter, are generally rounded and embayed by the groundmass; many are cut by small veinlets of calcite, quartz, and groundmass. Phenocrysts of feldspar are commonly 4 cm long. Some are partly replaced by sericite; others are replaced by calcite, epidote, and clay minerals. Only potassium feldspar was recognized, but some of the completely replaced crystals may originally have been plagioclase. Many of the potassium feldspar phenocrysts contain euhedral pyrite crystals and small, tabular, completely sericitized crystals that were probably plagioclase; some contain small disseminated grains of galena, sphalerite, pyrite, chalcopyrite, and pyrrhotite. A few clusters of chlorite, calcite, epidote, sericite, leucoxene, and pyrite in the rock were probably originally biotite or hornblende. Fresh euhedral apatite is a common accessory mineral.

Dikes of similar rocks occur in secs. 33 and 36, T. 9 N., R. 4 W. These rocks, which are not as intensely altered as those in secs. 26 and 35, contain many phenocrysts of plagioclase (An_{35}) and biotite in addition to large phenocrysts of potassium feldspar and rounded, broken phenocrysts of quartz. The rock making up one of these dikes also contains phenocrysts of hornblende.

In the NE¼ sec. 18, T. 6 N., R. 3 W., is a dike of light-greenish-gray porphyritic rock containing large phenocrysts of hornblende and smaller phenocrysts of plagioclase in an aphanitic groundmass. The dike is about 15 feet wide and about 600 feet long and appears to dip steeply to the northwest. Some of the hornblende phenocrysts are stubby, euhedral crystals as much as 2 cm long and others are laths that average about 3 mm in length. The laths are crudely alined with the lineation plunging 70° to 80° NW.—apparently down the dip of the dike. The plagioclase phenocrysts average about 1 cm in length and are partly altered to sericite.

All the dike rocks described cut the Butte quartz monzonite and resemble it in appearance and mineralogy much more closely than they resemble the later Tertiary volcanic rocks. The dike rocks were not observed in contact with the alaskite and their ages relative to it are uncertain.

AGE

The Butte quartz monzonite is Late Cretaceous or Paleocene in age. It cuts the folded Elkhorn Mountains volcanics and is therefore younger than Judith River in age (slightly older than middle Late Cretaceous). By early Oligocene time, erosion had exposed rocks of the batholith, for tuffs containing lower Oligocene vertebrate fossils were deposited directly on them. Thus, fossil evidence indicates that the Boulder batholith is post-middle Late Cretaceous and pre-early Oligocene in age.

Chapman and others (1955, p. 608–9) obtained ages of 69, 69 and 71 million years for 3 specimens of quartz monzonite and an age of 61 million years for 1 specimen of alaskite using the lead-alpha technique on zircon, and an age of 72 million years for the same specimen of alaskite using monazite. They conclude "* * * that the batholith was emplaced at or near the close of the Cretaceous." Knopf (1956, p. 744) gives a potassium-argon age determination of "most probably 87 million years" and "almost certainly older than 65 million years" for a small pegmatite schlier rich in potassium feldspar in a batholithic rock from the quarry about 1 mile west of Clancy. He concludes that this age "suggests "that the Boulder bathylith was emplaced in very late Cretaceous time."

POSTBATHOLITHIC VOLCANIC ROCKS

The youngest consolidated rocks in the Jefferson City quadrangle are quartz latite of the Lowland Creek volcanics, and rhyolite. Both were emplaced during the Tertiary period after a long period of erosion, during which most of the Elkhorn Mountains volcanics were removed and a mature erosion surface was developed on the underlying rocks of the batholith. As indicated by Knopf (1913, p. 41), the rhyolite and quartz latite seem to represent two distinctly different periods of volcanic activity. The two rocks differ in mineralogy and appearance, and they do not occur in the same parts of the quadrangle. According to Smedes (1962b), the Lowland Creek volcanics are late Oligocene in age. Ruppel (1963) describes rhyolite similar to that in the Jefferson City quadrangle and states that it is younger than the Lowland Creek volcanics; he considers it to be Oligocene(?) or Miocene(?) in age. The rhyolite in the Jefferson City quadrangle is therefore considered younger than the Lowland Creek volcanics.

QUARTZ LATITE

DISTRIBUTION AND GENERAL CHARACTER

The quartz latite in the Jefferson City quadrangle occurs as tuff, dikes, breccia bodies, and probably flows, mostly in a well-defined belt that extends from the southwest corner of the quadrangle northeastward to the east margin about 2 miles north of Jefferson City (pls. 2 and 3). A few small dikes are outside of this belt in the northeastern part of the quadrangle. Quartz latite tuff of the Lowland Creek volcanics covers a large area in the vicinity of Wickes, near the center of the quadrangle, and a small remnant of tuff and lapilli tuff occurs on the valley wall near the junction of Cataract Creek and Boulder River in the southwest corner of the quadrangle. The other quartz latite occurrences appear to be intrusive, except for a possible lava flow on the southeast slope of Sugarloaf Mountain. On this slope the contact of the quartz latite with the underlying batholith rocks appears to strike northeast and dip southeast. The underlying rocks appear weathered, but exposures are too poor to reveal whether a soil zone is present. Lava might have been extruded from a vent on Sugarloaf Mountain and flowed a short distance downslope.

The dikes range in thickness from a few inches to several hundred feet. Most of the dikes in the quadrangle dip steeply and trend approximately parallel to the trend of the general belt of quartz latite. Outcrops of the smaller dikes are generally low and rubbly, consisting of angular platy blocks, commonly 1 foot in diameter and a few inches thick, which are the result of breaking along closely spaced joints parallel to the walls of the dike. Flow banding in the smaller dikes almost invariably dips steeply. In the large dikes, platy jointing is not common, nor is flow banding common except in a few places.

The quartz latite in the dikes is light to dark gray, fine to medium grained, and porphyritic. Phenocrysts usually make up 10 to 40 percent of the rock, and rarely as much as 50 percent. Subhedral crystals of glassy plagioclase and subhedral to euhedral crystals of shiny black biotite are the most common phenocrysts. Subhedral to euhedral quartz phenocrysts are common in many specimens but absent in others. A few small dikes contain phenocrysts of hornblende.

A few of the dikes have glassy margins at their contacts with the enclosing rocks, and two bodies of green, devitrified glass occur in the N½ sec. 29, T. 8 N., R. 3 W. Areal distribution indicates that the west one is probably a dike, but the relations of the east body are not clear because of poor exposures.

Two intrusive breccia bodies consisting almost entirely of quartz latite were recognized in the quadrangle. One is in the northwest corner of sec. 23, T. 6 N., R. 5 W., near the junction of High Ore Creek and Boulder River; the other is in a railroad cut near the south margin of sec. 33, T. 7 N., R. 4 W. No extrusive quartz latite was recognized near the intrusive breccias; thus if the breccias occupy former vents and if quartz latite was deposited near the vents, subsequent erosion has removed all traces.

The breccia near High Ore Creek is in a pipelike body about 400 feet long and 50 to 80 feet wide that stands 10 to 50 feet above the surrounding rocks of the batholith. The fragments are angular, ranging in size from less than one-tenth of an inch to several inches. The only contact observed was a sharp vertical contact with a small alaskite dike at the northern margin of the pipe. The average size of the breccia fragments within a few inches of this contact is much smaller than the average size of the fragments throughout the remainder of the pipe. The alaskite is neither brecciated nor altered at the contact; however, several rounded, disaggregated fragments of quartz monzonite were found in the pipe within several feet of the contact. More than one period of brecciation is indicated by several large angular fragments that are composed of smaller angular fragments.

Most of the breccia fragments are moderately to intensely altered porphyritic quartz latite. Some are altered entirely to clay, limonite, and quartz; in others, the quartz and biotite are virtually unaltered but laths of plagioclase have been replaced entirely by chalcedony. A few fragments contain large irregular grains of calcite.

The fragments are cemented by very fine grained flow-banded quartz latite, which is unaltered and consists of irregular grains of quartz, feldspar, subhedral flakes of biotite, and glass. The banded appearance is apparently due to slight concentrations of crystals of quartz and feldspar in some bands, which are consequently a lighter shade of gray.

The second intrusive breccia, exposed in a railroad cut in sec. 33, T. 7 N., R. 4 W. (pl. 2), cuts rocks of the batholith and appears to cut dikes of flow-banded quartz latite. The large mass of intrusive breccia shown in plate 2 widens rapidly toward the east and thus the railroad cut may expose only the western end of a broadly elliptical, pipelike body. A deep cover of soil and vegetation conceals the breccia east of the railroad cut. The smaller masses of breccia shown in plate 2 are probably connected with the large mass to the east of the exposure in the cut.

The breccia consists principally of unsorted subangular to rounded fragments of batholithic rocks and porcellaneous quartz latite; it also includes fragments of flow-banded porphyritic quartz latite. A few vaguely outlined large fragments consisting of smaller fragments indicate more than one period of brecciation. Many fragments in the large breccia mass are more than 1 foot in diameter, but the average diameter appears to be only a few inches. In the smaller breccia masses, the maximum size of the fragments is about 6 inches and the average size is less than 1 inch. The fragments of batholithic rocks are thoroughly altered, but whether the alteration is the result of weathering could not be determined. The fragments of quartz latite appear relatively unaltered. The matrix of the breccia appears to be crushed mineral and rock fragments, and, except for fresh, shiny biotite fragments, the matrix appears to be largely altered to clay.

The batholithic rocks adjacent to the breccia are thoroughly stained by iron oxide, particularly along joints. Farther from the breccia, the staining is not as intense.

The extrusive quartz latite (Lowland Creek volcanics) in the vicinity of Wickes is poorly exposed and no individual units could be mapped. The rocks are all fragmental and range from very fine grained tuffs with an average grain size of less than 0.1 mm to breccia or tuff breccia with fragments as much as 10 cm across. The fragments are of quartz and plagioclase crystals, quartz latite, and quartz latite tuff. They generally contain little biotite and in this way differ markedly from the intrusive quartz latite. The extrusive rocks in this area are cut by many north to northeast trending dikes of quartz latite that are more resistant to weathering and commonly form low ridges in the easily weathered tuffs.

A tuffaceous conglomerate or breccia pipe is exposed in a shallow pit at the Montana Tunnels near the center of sec. 8, T. 7 N., R. 4 W. The mass consists largely of well-rounded pebbles, cobbles, and boulders of Elkhorn Mountains volcanics and batholithic rocks, but also contains a few pebbles of quartz latite in a tuffaceous matrix. It is not bedded and contains neither silt nor sand. The rock is in contact with a fine-grained quartz latite tuff, and the attitude of the contact is N. 30° E., 80° NW. Inasmuch as the exposure is near the edge of the area of tuff and the included cobbles are rounded, the rock may be a conglomerate at or near the base of the tuff. However, its location in an area of volcanic activity and its tuffaceous matrix suggest that the mass could be a breccia pipe.

PETROGRAPHY

The intrusive quartz latite generally consists of phenocrysts of glassy plagioclase, quartz, and thin hexagonal crystals of biotite in a very fine grained groundmass of quartz, feldspar, biotite, and, rarely, glass. Phenocrysts commonly make up 10 to 40 percent of the rock. Accessory minerals, including apatite, zircon, sphene, magnetite, and ilmenite, do not exceed 2 percent. Specks of clay are abundant in most of the rocks.

The plagioclase phenocrysts constitute 10 to 35 percent of the rock. They are subhedral to euhedral and are commonly embayed by and contain inclusions of the groundmass. Some crystals are unzoned and others have complex, oscillatory zoning. The composition is generally within the range of An_{25} to An_{45}. Some crystals are partly to completely replaced by sericite, calcite, zoisite, and clay minerals.

Quartz phenocrysts normally make up 1 to 10 percent of the rock, but they are completely absent in some specimens and are as much as 20 percent of others. They are commonly euhedral; many are rounded and embayed by the groundmass. The quartz usually has sharp extinction. Inclusions of glass, apatite, and zircon are not uncommon.

Biotite phenocrysts normally are 5 to 15 percent of the rock, but in a few specimens they are absent. Biotite occurs as thin platy crystals, often broken or bent parallel to flow lines. Pleochroic colors are pale yellow (X) to dark brown and dark greenish brown (Y and Z). Inclusions of apatite are common; zircon and magnetite are less common. Some biotite is altered to a colorless mica and penninite, and some is completely replaced by iron oxide.

Phenocrysts of potassium feldspar were recognized in only two specimens, where they make up 10 percent of one and about 2 percent of the other. The phenocrysts are generally clear and euhedral. The feldspar has a small negative axial angle and is probably sanidine.

Amphibole phenocrysts are sparse, but in one specimen amphibole makes up about 10 percent of the rock—in this specimen biotite is absent. The amphibole, probably near hornblende in composition, occurs as subhedral to euhedral phenocrysts, and most of it is twinned and weakly zoned. Pleochroism is weak with tints ranging from colorless (X) to pale brown (Y) and pale greenish brown (Z). The extinction angle measured on (010) is 20°, and the maximum birefringence is about 0.015.

The groundmass is generally a very fine grained aggregate of feldspar, quartz, and biotite. Some specimens contain large amounts of partly devitrified glass. The average grain size of the groundmass is about 0.02 mm. Some streaming of the groundmass around phenocrysts is evident from the orientation of the biotite flakes and feldspar laths.

COMPOSITION

The quartz latite has been referred to in earlier reports as dacite (Knopf, 1913, p. 38); andesite porphyry, dacite porphyry, and andesite (Roberts and Gude, 1953a, p. 75); and dacite and andesite (Becraft, 1953, p. 5). Weed referred to similar rocks at Butte as rhyolite in the Butte folio and subsequently as rhyolite-dacite (Weed, 1912, p. 43). If only the identifiable minerals are considered in naming the rocks, most are either dacite or andesite, depending on the presence or absence of quartz. Only one specimen examined contained enough recognizable potassium feldspar to be quartz latite.

Chemically the rocks are within the quartz latite range. Chemical analyses (table 8) and computed norms (fig. 26) of four samples from the Jefferson City

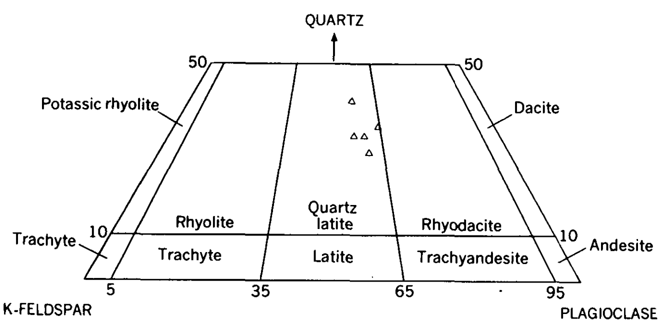


FIGURE 26.—Triangular diagram showing relative proportions of normative quartz, potassium feldspar, and plagioclase computed from five chemical analyses of Tertiary quartz latite. Feldspar and quartz recalculated to 100 percent.

quadrangle and one from the adjoining Basin quadrangle indicate that much of the feldspar in the groundmass that is too fine grained to be identified microscopically must be potassium feldspar. Thus, the phenocrysts do not indicate the true composition of the rock. Because the chemical analyses of five specimens collected from different localities bear a close similarity and are all within the quartz latite range, the rocks are referred to in this report as quartz latite.

TABLE 7.—*Chemical analyses and norms of quartz latite of Tertiary age*

[Analysts: H. F. Phillips, P. L. D. Elmore, K. E. White, F. S. Borris, and J. M. Dowd]

Field No.	3BC10 [1]	3BC12 [1]	2C72 [1]	2C104 [1]	4R9c [2]
Laboratory No.	53-2222-SC	53-2224-SC	53-1862C	52-2134CW	139538
Chemical analysis					
SiO_2	67.1	70.3	68.5	67.6	68.1
Al_2O_3	15.4	15.5	15.5	14.6	15.5
Fe_2O_3	.8	1.1	.8	1.0	1.0
FeO	1.0	83	1.0	.96	.95
MgO	1.0	.80	1.1	.97	1.2
CaO	3.8	1.6	2.6	2.6	2.5
Na_2O	1.2	3.3	2.8	2.4	3.2
K_2O	3.8	4.2	3.5	4.5	4.3
TiO_2	.27	.26	.31	.34	.32
P_2O_5	.10	.08	.14	.06	.12
MnO	.02	.02	.08	.03	.04
H_2O	3.4	1.3	4.0	4.0	3.2
CO_2	2.6	<.05			<.05
Norm					
Quartz	37.7	31.7	32.9	31.4	26.8
Orthoclase	23.9	25.3	21.1	27.8	26.1
Albite	11.0	28.5	24.6	21.0	27.8
Anorthite	18.9	7.3	13.3	13.3	12.8
Corundum	2.9	3.1	2.5	1.3	1.0
Hypersthene	3.6	2.0	3.5	3.8	3.5
Magnetite	1.2	.2	1.1	1.6	1.4
Ilmenite	.6	.6	.6	.8	.6

[1] Intrusive quartz latite, for location of specimens see pl. 1.
[2] Quartz latite welded tuff cited by Ruppel (1963)

RHYOLITE

DISTRIBUTION AND GENERAL CHARACTER

Rhyolite is restricted to the northwestern part of the quadrangle except for a small body in sec. 26, T. 7 N., R. 5 W., about 1 mile northwest of the Comet mine. The largest body of rhyolite is on Red Mountain; Lava Mountain and Spruce Hills also include rhyolite. Most of the small rhyolite bodies are flow remnants, but a few small dikes occur east of Red Mountain and in the vicinity of Spruce Hills in sec. 6, T. 8 N., R. 4 W. A large part of the rhyolite on Red Mountain is probably also intrusive.

Most of the rhyolite is light pinkish gray to red, but some is green, gray, or black. The rock is porphyritic and has abundant anhedral phenocrysts of smoky quartz and euhedral phenocrysts of sanidine. Flow banding is well developed in much of the rhyolite (fig. 27), and platy jointing parallel to the flow banding is common. Locally, individual flow bands can be traced for as much as 20 feet.

The large body of rhyolite on Red Mountain is similar throughout the entire exposure except on the northwestern slope of the mountain, where it has a more massive appearance. Most of the rock is extremely well jointed and flow banded. Frost heaving has made most outcrops look like large piles of rubble (fig. 28), but

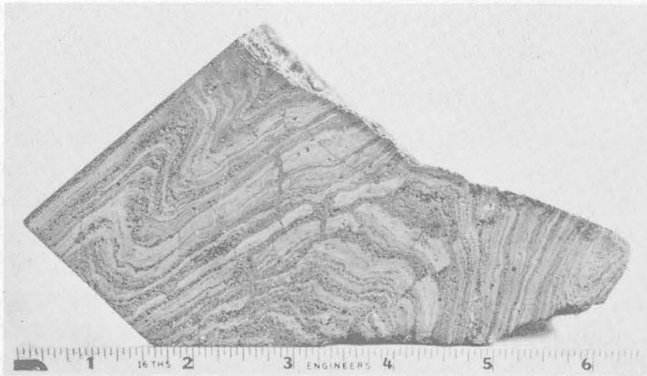


FIGURE 27.—Photograph of a specimen of rhyolite from Lava Mountain showing flow bands that were folded and broken while the rock was still mobile.

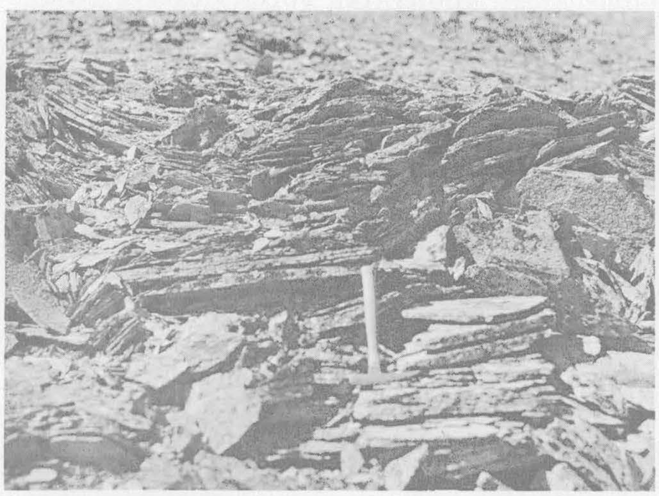


FIGURE 28.—Photograph showing a typical frost-heaved outcrop of rhyolite near the top of Red Mountain.

enough rhyolite is in place to determine that the strike of the platy jointing and parallel flow banding is extremely irregular. The dip of the banding is almost invariably steep—usually within a few degrees of vertical. At the crest of the mountain and on the southeastern slope, the rock is slightly vesicular; many of the vesicles are elongated parallel to the flow bands and joints and are lined with small quartz crystals. Alteration has commonly caused bleaching parallel to the joints, extending into the rock for irregular distances, but generally not more than about a centimeter. The alteration is probably the result of gasses streaming upward late in the crystallization of the rhyolite. Near the crest of the mountain the rock is cut by veins of jasper, some of which are as much as 2 feet thick.

The contact between the rhyolite and rocks of the batholith on the western and northern slopes of Red Mountain appears to be almost horizontal, but the contact on the southeastern slope dips steeply. The difference in elevation between the top of Red Mountain and the lowest outcrop of rhyolite is about 1,500 feet on the western side of the mountain and about 1,200 feet on the eastern side. Thus, the maximum thickness of rhyolite appears to be between 1,200 feet and 1,500 feet, which is considerably greater than the thickness of any of the recognized flows in the Jefferson City quadrangle or in the adjoining Basin quadrangle to the west (Ruppel, 1963).

The rhyolite on Red Mountain appears to be largely intrusive because of the considerable thickness, the similarity of the rock throughout the mass with no obvious horizontal layering, the consistently steep dip of the flow banding at the crest and on the southeastern slope of the mountain, and the alteration along the platy joints parallel to the flow bands. The rhyolite probably broke through to the surface and flowed a short distance to the north and west, which would account for the nearly horizontal contacts on these slopes.

Two types of flow banding are common in the rhyolite. In the most common type, the ratio of quartz and sanidine crystals to devitrified groundmass is different in adjacent bands. Some bands consist almost entirely of anhedral to euhedral crystals of quartz and sanidine, and other bands consist almost entirely of spherulitic devitrified glass. In the other common type of flow banding, the ratio of crystals to devitrified groundmass is about the same in adjacent bands, but the sizes of the spherulites differs greatly. In many specimens, some of the flow bands are warped around rhyolite fragments and others are cut by the rhyolite fragments. These fragments must have been solid at the time the flow bands were formed, thus indicating that movement continued after some of the rhyolite was solidified. No fragments of rocks other than rhyolite were observed.

Clark (1910, p. 80) gives a chemical analysis of rhyolite from the top of Red Mountain (table 9). This analysis is apparently of unaltered rhyolite and, as Knopf (1913, p. 40) says, "* * * is doubtless typical of the rhyolite generally." In table 9 it is compared with an analysis of an altered light-gray rhyolite from the southeastern slope of Red Mountain. Apparently silica and potassium have been added to the altered rock and sodium and iron have been removed. The relations of the altered rhyolite to the unaltered rhyolite could not be determined because of soil cover. No quartz veins were observed in the vicinity of the altered rhyolite. The rock was probably altered by late deuteric solutions, and the alteration is probably similar to that along joints as described above.

TABLE 8.—*Chemical analyses of rhyolite from Red Mountain*

	1	2
SiO_2	75. 30	81. 8
Al_2O_3	11. 95	10. 6
Fe_2O_3	2. 17	. 46
FeO	------------	. 22
MgO	. 05	. 17
CaO	. 62	. 12
Na_2O	3. 09	. 40
K_2O	4. 96	5. 4
TiO_2	. 17	. 08
P_2O_5	Trace	. 02
MnO	Trace	. 01
H_2O	. 97	. 85
CO_2	None	. 05
SO_3	. 44	------------

1. Cited by Clarke (1910, p. 80), rhyolite from top of Red Mountain. Analyst: H. N. Stokes.
2. Altered rhyolite from southeast slope of Red Mountain, 3BC11 on pl. 1. Analysts: H. F. Phillips, P. L. D. Elmore, and K. E. White. Laboratory No. 53-2223-SC.

PETROGRAPHY

Phenocrysts of sanidine and quartz constitute from a few percent to as much as 25 percent of the rhyolite, and in a few sections there are sparse phenocrysts of plagioclase and biotite. Zircon is a sparse accessory. The phenocrysts of sanidine are commonly euhedral and have sharp boundaries with the groundmass. Many of the sanidine phenocrysts are as much as 7 mm long but the average is about 1 mm. Some of the euhedral sanidine crystals consist largely of intergrowths of vermicular quartz and sanidine.

The quartz phenocrysts are anhedral to subhedral crystals which commonly range from less than 1 mm to 3 mm. The crystals are commonly rounded and many have sharp boundaries with the groundmass; in some crystals, the groundmass has partly replaced the quartz around the margins and along fractures in the crystals. In some of the rhyolite, the grain size of the groundmass is slightly coarser than normal in an irregular rim about 0.1 mm thick around all of the quartz phenocrysts. This coarser grained material appears to be largely quartz and sanidine, but may also include some albite.

The groundmass is commonly devitrified glass, but in a few sections the devitrification has not been complete. Spherulites are common; they range from almost submicroscopic to 0.2 mm and average about 0.1 mm. A few of the spherulites have cores of hematite. In some of the glassy specimens, the perlitic cracks are lined with bladed-crystal aggregates—axiolites—in which the crystals extend about 0.05 mm into the glass from the cracks. Much of the glass is devitrified and consists of almost submicroscopic spherulites. Grains of hematite, usually less than 0.01 mm in size, are common in the groundmass of some rhyolite and probably account for the common reddish tint of the rhyolite.

STRUCTURAL FEATURES

Major structural features in the Jefferson City quadrangle include a broad syncline in the prebatholithic Elkhorn Mountains volcanics, many joint sets in the batholithic rocks, shear zone [2] that commonly contain quartz or chalcedony veins, nonmineralized faults, and probable faults recognized by topographic lineaments. Alaskite dikes and quartz latite dikes have preferred attitudes and probably occupy fractures. Primary linear and planar structures in the batholithic rocks are vague and too indefinite to map.

FOLDING AND FAULTING IN THE ELKHORN MOUNTAINS VOLCANICS

The Elkhorn Mountains volcanics in the large roof remnant near the center of the quadrangle have been folded into a broad syncline which plunges to the southeast. Minor irregularities have been produced in the major structure by subsequent faulting, but the syncline is well illustrated by the distribution of the middle and upper units of the volcanics and by the attitudes of bedding in the upper unit.

The syncline is cut by a northward- to northeastward-trending major fault about 1½ miles from the eastern margin of the roof remnant. The block east of the fault was uplifted and the upper unit of the Elkhorn Mountains volcanics was removed from this block by erosion prior to the deposition of the Lowland Creek volcanics. The fault extends northward from the roof remnant into the Butte quartz monzonite and occupies the valley of Clancy Creek for about a mile. A sharp change in topography along the extended trace of the fault indicates that the fault may continue several miles farther north. The most recent movement along the fault postdates the Tertiary quartz latite and appears to have been opposite to the earlier movement, that is, the east block moved down. A second fault parallel to the major fault at the northern margin of the roof remnant has offset the contact of the Elkhorn Mountains volcanics and the Butte quartz monzonite. The east block moved down along this fault also. Whether these two faults are really separate faults or part of a broad fault zone is not known, but the parallelism and the similarity of movement along the faults indicate that they resulted from the same forces probably at about the same time.

Another fault, which trends eastward, cuts the upper unit of the volcanics in Wood Chute Gulch and appears

[2] Shear zone is used in this report in a purely descriptive sense to mean a zone of closely spaced surfaces on which one wall has moved relative to the other producing slabs or slivers of rock.

to offset the contact between the quartz latite tuffs of the Lowland Creek volcanics and the upper unit of the Elkhorn Mountains volcanics. This fault is parallel to eastward-trending shear zones and the earliest movement along it may have occurred at about the same time that the shear zones were formed, even though no hydrothermal alteration or veins were observed along the fault.

Many other faults cut the Elkhorn Mountains volcanics and some cause local reversals of dip in the bedding of the upper unit. Several eastward-trending shear zones and many quartz latite dikes also cut the roof remnant; these are discussed in a later section.

JOINTS

Many joints cut the batholithic rocks in the Jefferson City quadrangle, but no joint sets are consistent over the entire quadrangle. In some areas several square miles in extent, most joints can be assigned to definite sets of one system, but in other areas totally different joint systems exist in outcrops only a few hundred feet apart horizontally and vertically. Undoubtedly many of the joints were formed during the cooling of the rock, but many others are also the result of regional stresses. The cooling history of the batholith was complex, and the lack of primary features with which to relate joints resulting from cooling makes recognition of such joints impossible. Also, large areas of batholithic rocks are covered by mantle, and information on the joints in these areas could not be obtained. Thus, although the attitudes of many hundreds of joints were recorded during field work, no interpretation of the jointing in the quadrangle is feasible at this time. An intensive study of all joints and lineaments in selected areas containing a well-defined type of Butte quartz monzonite, such as the areas in and around the fdo body east of the Spruce Hills, the fl body east of Rimini, or the fl body in the southeast corner of the quadrangle (pl. 1), might provide information that would lead to a better understanding of the joints in the remainder of the quadrangle.

Many small alaskite dikes ranging from less than 1 inch to many feet in thickness appear to have been intruded along joints. The dikes commonly follow one joint for a short distance and then another, differently oriented joint. The attitudes of these dikes commonly persist for only short distances, and the changes are sharply angular. Many of the small dikes appear to have been feeders for flat-lying dikes. The flat-lying dikes are commonly parallel to nearby joints, which suggests that these dikes were also intruded along joints.

LARGE ALASKITE DIKES

Much of the alaskite in the Jefferson City quadrangle is in large dikes that extend for many hundreds of feet with apparently only slight changes in attitude. In most cases, the attitudes of these dikes could not be accurately measured because of poor outcrops, but most of the dikes appear to dip either steeply, from 70° to 90°, or nearly horizontally, from 0 to 20°. In order to determine whether a preferred orientation of the steeply dipping dikes exists, all those shown on plate 1 that are over 400 feet long and have persistent trends were plotted on plate 3, and the trends of 513 dikes were plotted in 10° increments on a compass rose (fig. 29). The plots

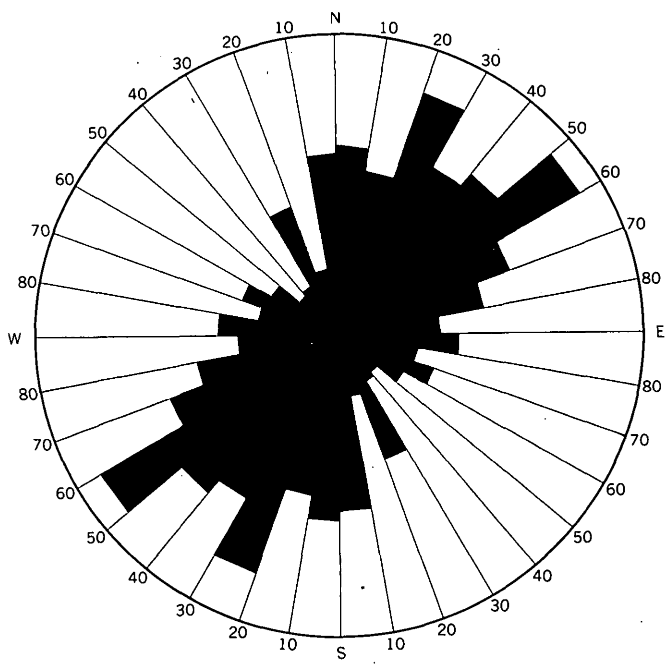


FIGURE 29.—Trends of 513 steeply dipping alaskite dikes in the Jefferson City quadrangle plotted in 10° increments on a compass rose.

show that the dikes have a definite northeastward preferred orientation. Two orientations are most common—N. 50°–60° E. and N. 20°–30° E.

SHEAR ZONES

Many shear zones cut the Elkhorn Mountains volcanics and the rocks of the batholith. They range from a few feet to as much as 500 feet in width and from a few hundred feet to about 6 miles in length. Many of the zones contain quartz veins and metallic mineral deposits. Almost all are complexly fractured and contain much fault gouge. Several generations of brecciated vein minerals indicate that movement was repeated and perhaps extended over a considerable period of time, but no evidence of large-scale displacement has been observed. The Comet-Gray Eagle shear zone, which is the widest and longest in the quadrangle, cuts the contact between Elkhorn Mountains volcanics and the batholith in four places with no apparent offset. A split of this shear zone in sec. 32, T. 7 N., R. 4 W., appears to offset the contact, but probably less than 100 feet.

The distribution and trends of shear zones that contain quartz veins are shown on plate 3; other shear zones are probably present in the quadrangle but may not have been mineralized and thus were not recognized. Most of these zones are near the center or in the western half of the quadrangle; noteworthy exceptions are the veins in the Clancy mining district in the northeast corner of the quadrangle.

The trends of the shear zones were measured and plotted in 10° increments on a compass rose (fig. 30).

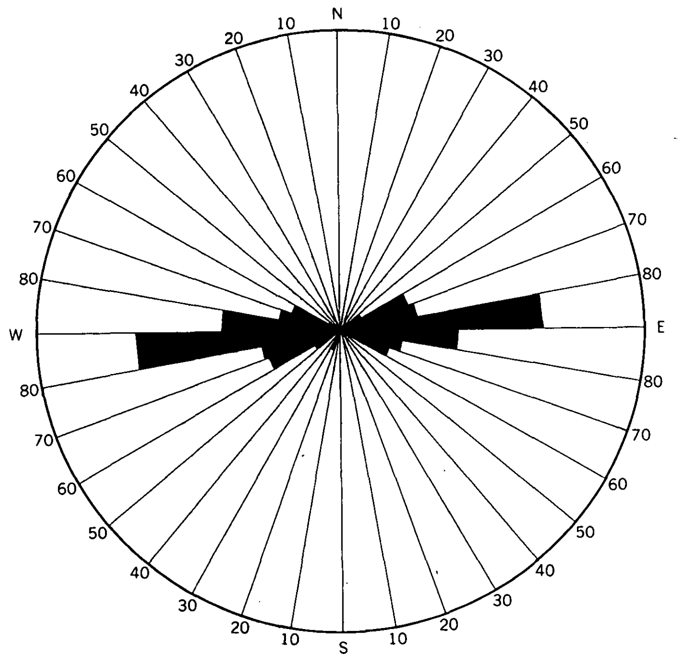


FIGURE 30.—Trends of 132 shear zones in the Jefferson City quadrangle plotted in 10° increments on a compass rose.

Most of the zones trend within 10° of east, and almost all are within 30° of east. Similar shear zones in the adjoining Basin quadrangle have the same orientation (Ruppel, 1963). Some shear zones cut alaskite dikes, but shear zones are almost absent in areas where alaskite dikes are relatively abundant (pl. 3). Quartz latite dikes of Oligocene age cut the shear zones and are not sheared or altered; two examples are in secs. 17 and 18, T. 7 N., R. 4 W.

CHALCEDONY VEIN ZONES

Rocks of the batholith, particularly near the southwest corner and in the northeastern part of the quadrangle (pl. 3), have been repeatedly brecciated and silicified along steeply dipping fractures to form chalcedony vein zones. These zones consist of one or more discontinuous stringers and veins of chalcedony and microcrystalline quartz in altered quartz monzonite and granodiorite and in alaskite that is only slightly altered. Crosscutting relations of several veinlets in a few vein zones indicate as many as four distinct periods of brecciation and silicification.

The trends of 255 chalcedony vein zones shown on plate 3 were measured and plotted in 10° increments on a compass rose (fig. 31). Almost all of the vein zones trend between N. 40° E. and S. 80° E. with the maximum between N. 50° E. and N. 70° E.

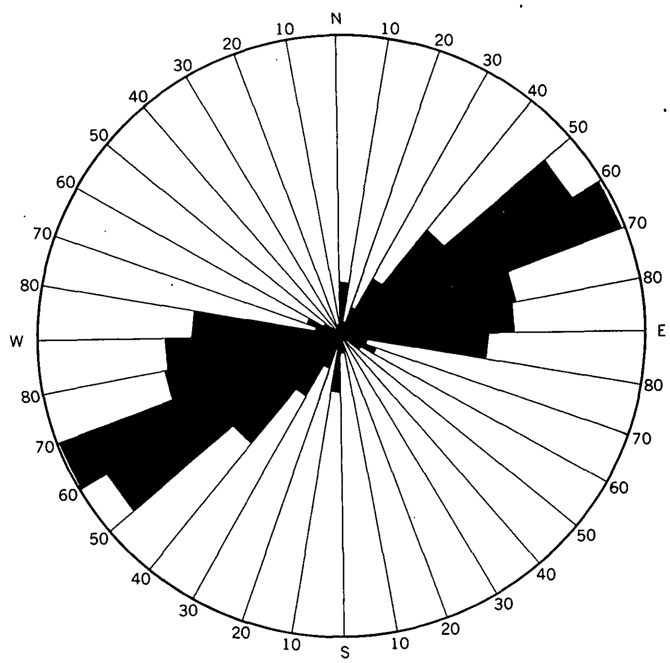


FIGURE 31.—Trends of 255 steeply dipping chalcedony vein zones in the Jefferson City quadrangle plotted in 10° increments on a compass rose.

QUARTZ LATITE DIKES

The well-defined belt of quartz latite dikes trends generally northeastward from the southwest corner of the quadrangle to the east margin about 2 miles north of Jefferson City and, according to Smedes (1962a), extends into the Clancy quadrangle to the east. Although the general trend of the belt is northeastward, the trend changes gradually to north-northeastward in the area of quartz latite tuff of the Lowland Creek volcanics near the center of the quadrangle and then abruptly back to northeastward (pls. 1 and 3). Most of the individual dikes follow the general trend of the belt and appear to dip nearly 90°. A few dikes that trend more to the north are present outside of this belt in the northeastern part of the quadrangle. The trends of 177 dikes are plotted in 10° increments on a compass rose in figure 32. They are largely between north and N. 60° E. Very few dikes trend northwestward.

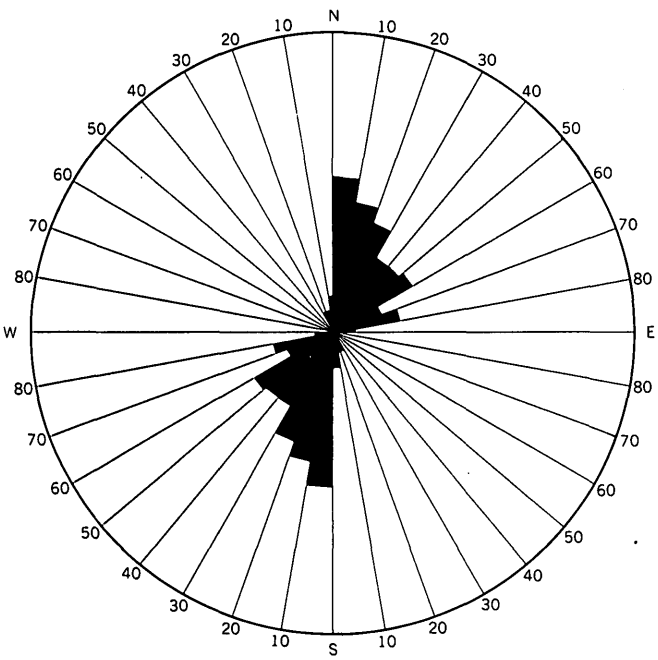


FIGURE 32.—Trends of 177 Tertiary quartz latite dikes in the Jefferson City quadrangle plotted in 10° increments on a compass rose.

The dikes cut earlier formed structures with no apparent offsetting along the dikes. No evidence of brecciation was observed in the enclosing rocks. Inclusions of the host rocks are extremely rare except in the two breccia plugs described earlier.

NONMINERALIZED FAULTS

Many nonmineralized faults were observed in mines, but only a few, such as the Red Mountain fault, could be traced on the surface. Other faults may be indicated by many topographic lineaments—unusually straight or aligned stream valleys. A compilation of the trends of 142 faults and lineaments on a compass rose indicates that the dominant trend is N. 50°–60° E., but that trends of north to N. 10° E., N. 30°–40° W., and N. 80° W. to west are common (fig. 33). These trends may not indicate the dominant trends of the nonmineralized faults because of the small number of faults that were mapped.

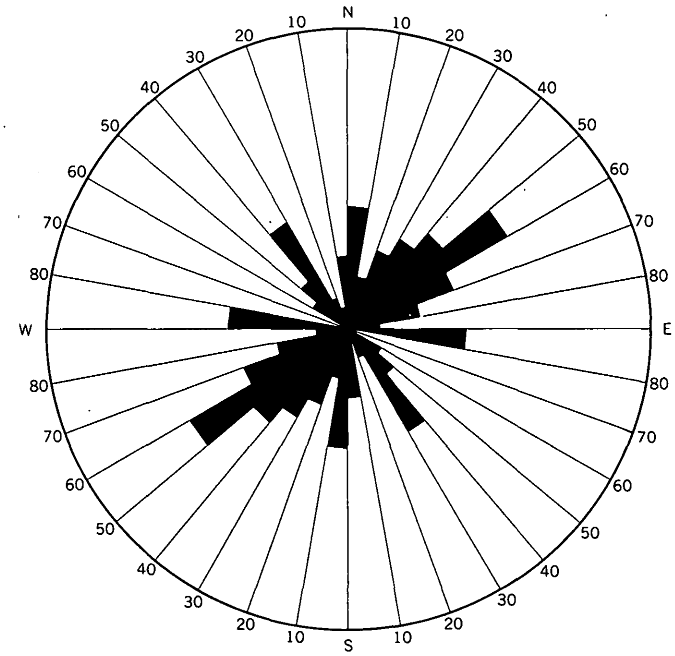


FIGURE 33.—Trends of 142 nonmineralized faults and topographically expressed lineaments in the Jefferson City quadrangle plotted in 10° increments on a compass rose. Each fault or lineament is represented by 0.1 inch.

The Red Mountain fault trends northward through the md unit of the Butte quartz monzonite in the northwestern part of the quadrangle (pl. 1). The fault is expressed topographically by many short gulches and streams, on the basis of which it can be followed southward at least as far as the landslide east of the Evergreen mine (No. 15, pl. 1) and possibly to a wide north-trending shear zone in the east end of the Alley mine (No. 16, pl. 1). The fault extends northward at least to the glacial deposits along Beaver Creek and probably beyond. Where exposed in the Red Mountain Tunnel (No. 8, pl. 1) the fault is a brecciated zone 20 to 40 feet wide that strikes about N. 7° E. and dips 65° W. It offsets several major mineralized quartz veins. The horizontal component of movement on the fault is not known; it may be about 600 feet if tentative correlations across the fault are correct.

STRUCTURAL HISTORY

The syncline in the Elkhorn Mountains volcanics is the oldest structural feature in the quadrangle. It probably is contemporaneous with the Laramide deformation of rocks in the Elkhorn Mountains and the Townsend Valley farther east (Klepper, Weeks, and Ruppel, 1957; Freeman, Klepper, and Ruppel, 1958) and with broad, gentle folding in the Elkhorn Mountains volcanics in the Basin quadrangle (Ruppel, 1963).

The dominant northeastward trends of the large alaskite dikes, chalcedony veins, and quartz latite dikes in the Jefferson City quadrangle are probably due to recurring regional forces active since the emplacement of the Boulder batholith and possibly even earlier. The same or similar forces may have partly controlled the emplacement of the batholith, which is also elongate in a northeastward direction. During the cooling period of the batholith, these regional stresses apparently produced steeply dipping fractures with attitudes persistent for many hundreds of feet and, rarely, thousands of feet, which are occupied by the large alaskite dikes. This fracturing took place after large volumes of an alaskitic differentiate had formed from the parent magma but probably before the batholith had cooled to a great depth. The batholithic rocks that fractured had not cooled sufficiently to produce chilled margins in the alaskite dikes. Smaller, irregular alaskite dikes were probably intruded along joints that formed as a result of cooling of the shell of the batholith. They may represent local segregations of alaskitic magma that moved only a short distance before crystallizing.

Other eastward-trending shear zones and northeastward-trending chalcedony vein zones cut alaskite dikes and thus are younger than the fractures occupied by the alaskite. Many of the shear zones are cut by north- and northeast-trending dikes of quartz latite and thus are older than the fractures along which these dikes were intruded. The eastward-trending shear zones might possibly be tensional features that resulted from the same recurring regional forces that produced the many northeast-trending structures. Complete interpretation of the structural features in the Jefferson City quadrangle cannot be made until the detailed study of the Boulder batholith and surrounding rocks is completed.

COMPARISON WITH ADJACENT AREAS

Although much of the interpretation of the geology must be deferred until completion of the detailed study of the entire Boulder batholith, of which the Jefferson City quadrangle covers only a small part, certain significant differences and similarities between the geology of the Jefferson City quadrangle and adjacent areas can be summarized. These areas are shown on figure 1; they were mapped as follows: The Basin quadrangle by Ruppel (1963); the Elk Park quadrangle by Smedes, Klepper, Pinckney, Becraft, and Ruppel (1962); the eastern half of the Boulder quadrangle by Klepper and Weeks; the western half of the Boulder quadrangle by Becraft and Pinckney (1961, and Pinckney and Becraft, 1961); the northern half of the Clancy quadrangle by Smedes (1962a) and the southern half by Klepper, Weeks, and Ruppel (1957). The Helena quadrangle is included in an area discussed briefly by Knopf (1957).

Early-stage rocks of the batholith.—Early-stage batholithic rocks named 'Unionville granodiorite" by Knopf (1957, p. 90) crop out in a generally eastward-trending belt in the Helena quadrangle and extend southward to within one-tenth of a mile of the Jefferson City quadrangle. No early-stage batholithic rocks were recognized in the Jefferson City quadrangle.

Butte quartz monzonite.—Most of the Butte quartz monzonite in the Jefferson City quadrangle would apparently be included in the Clancy granodiorite of Knopf (1957, p. 91). Knopf named the Clancy granodiorite from the Kain quarry on Clancy Creek. This is the type locality of the clo unit of the Butte quartz monzonite of this report.

The rock mapped by Knopf as biotite adamellite is petrographically and chemically similar to the main-stage rock type ml of this report. Knopf states that the biotite adamellite is younger than the Clancy granodiorite and is thus a separate pluton. In the Jefferson City quadrangle, no such age relations were observed, and the ml does not appear to be a separate pluton from the other types of Butte quartz monzonite.

The Butte quartz monzonite east and south of the Jefferson City quadrangle is relatively homogeneous—largely coarse-grained (cl and clo) rocks, with a few small areas of other types near the eastern margin of the batholith. West of the quadrangle, the Butte quartz monzonite rock types crop out in arcuate bands, roughly parallel to the contact of the batholith with prebatholithic rocks, and the contact appears to be stratigraphically controlled. No such pattern is apparent in the Jefferson City quadrangle, and the Butte quartz monzonite cuts across the structure in the Elkhorn Mountains volcanics with no suggestion of stratigraphic control.

Alaskite.—Alaskite is sparse in the Basin quadrangle, and the few steeply dipping dikes have no preferred orientation. Almost all of alaskite dikes are nearly horizontal rather than steeply dipping, and this is also true in the quadrangles south and east of the Jefferson City quadrangle. In the Boulder and Elk Park quadrangles the contacts of alaskite dikes with Butte quartz monzonite are commonly less sharp, and pegmatitic clots in the quartz monzonite, ranging from less than one inch to many inches in diameter, are more common. Relatively little alaskite occurs near the eastern margin of the batholith.

Quartz latite.—The belt of quartz latite dikes so prominent in the Jefferson City quadrangle extends across the southeast corner of the Basin quadrangle to a large area of extrusive quartz latite (Lowland Creek volcanics) that covers much of the northern part of the Elk Park quadrangle. Only two small dikes of quartz latite were observed in the Boulder quadrangle. The belt also continues northeastward across the northern part of the Clancy quadrangle, but it contains fewer dikes than in the Jefferson City quadrangle and thus is not as well defined.

Rhyolite.—The rhyolite in the northwestern part of the Jefferson City quadrangle is at the end of a poorly defined belt of rhyolite that extends northeastward across the Basin quadrangle.

Veins.—Most of the ore produced in the northern part of the batholith has come from quartz veins along east-trending shear zones, as in the Jefferson City quadrangle. Similar quartz veins along east-trending shear zones are sparse in the Boulder quadrangle and in the Clancy quadrangle, where they are confined to the northwestern part.

The area of numerous chalcedony veins in the northeastern part of the Jefferson City quadrangle extends a few miles into the Clancy quadrangle, where the veins are dominantly east trending rather than northeast trending. The area of numerous chalcedony veins near the Boulder River (pls. 1 and 3) extends about 3 miles south of the quadrangle. No chalcedony veins have been mapped farther south, and none were recognized in the Basin quadrangle west of the Jefferson City quadrangle.

Joints.—Most of the joints in the batholithic rocks in the Basin quadrangle are in one main joint system consisting of three main joint sets. In the Boulder quadrangle north of the Little Boulder River (fig. 1), the joints are as irregular as those in the Jefferson City quadrangle, but for some distance south of the Little Boulder River all the joints belong to one nearly vertical set that strikes N. 20° W. to N. 20° E., and they are commonly less than 1 inch apart.

Glaciation.—The glacial ice in the Jefferson City quadrangle was the eastern limit of an ice sheet that covered most of the Basin quadrangle.

MINERAL DEPOSITS

The mineral deposits in the Jefferson City quadrangle occur almost entirely in veins along sheared or brecciated zones. Deposits of base and precious metals in quartz veins have been valuable chiefly for their silver content; most of them also contain large amounts of lead and zinc and smaller amounts of gold and copper. Argentiferous galena and sphalerite are the chief ore minerals; chalcopyrite, associated with some tetrahedrite, is a minor constituent of most ores and is locally abundant. Chalcedony veins in the quadrangle are generally barren of sulfide minerals; however, many chalcedony veins, and some quartz veins, contain small amounts of uranium.

A few other types of mineral deposits are found in the area. These include a mineralized breccia pipe, a mineralized conglomerate (or possibly another breccia pipe), placer deposits of gold, bog manganese deposits, and a bog deposit of native copper.

General features of the mineral deposits in the quadrangle are discussed in the following pages of this report; a fuller, more detailed study of mineral deposits in the region has been made by Pinckney (written communication, 1962). The location of many mines and prospects is shown on figure 3, and the operations referred to in the text are identified by numbers enclosed in parentheses. Although most of the mines were inaccessible in 1950–53, much information about them was assembled as the quadrangle was mapped, and this information is presented in the detailed descriptions of mining districts and mines.

HISTORY OF MINING IN THE REGION

The discovery of gold placers on Grasshopper Creek at Bannock in 1863, and of much larger placers in Alder Gulch near Virginia City in the same year, brought many prospectors to Montana. The first mineral discovery in the Helena region was the Last Chance placer, found in 1864 at the present site of Helena; by the end of 1864, prospectors had also found placers on Tenmile Creek. Placer deposits first were discovered in the Jefferson City quadrangle in 1865; they were not bonanzas like the Last Chance and Alder Gulch placers, but several were very successful for a short time.

Lode deposits also were discovered in the Helena region in 1864, including the Whitlatch-Union near Helena, the Gregory (63) and Minah (49) near Wickes, and the Lee Mountain (1) near Rimini. Other large deposits were found during the following years, and much of the highest grade near-surface ore was mined for its silver content. Freight rates were high, however, and treatment of the ore was expensive. Lode mining was therefore restricted to the richest deposits until the Northern Pacific Railway reached Helena in 1883 (Knopf, 1913, p. 15–16).

During this early period of mining, lead in the ore was worth very little and zinc was worthless. Miners recognized the need for treatment plants to separate the valuable constituents from the gangue. The first such plant in the area was a smelter built at the Gregory mine (63) in 1867 (Knopf, 1913, p. 16). Other early-day smelting plants were built at Wickes, south of Amazon, and at the Minah mine (49); concentrators using gravity methods operated at Rimini, Corbin, Comet, and the Eva May (77) mine (Montana Inspector of Mines, 1889, p. 69). Most of these plants were inefficient.

In 1883, when the railroad was extended to the mining camps of Rimini and Wickes, the small reduction plant at Wickes was remodeled and enlarged and lead, as well as silver became a valuable constituent of the ore. This incentive started a mining and prospecting boom that lasted until the silver panic of 1893. The Alta mine (67) was a chief source of ore for the Wickes smelter and proved to be the most productive mine in the Helena region. The Comet mine (100) and many others in the Jefferson City quadrangle also flourished during this period.

After the silver panic, little money was available for exploration or development, and many of the lode miners did not resume operations on their former scale. Most of the mines had been developed as deeply as was possible by adits, and shaft operations powered by wood-fired steam plants were expensive. Furthermore, most of the oxidized near-surface ore and the mineralogically simple bodies of silver-lead sulfide ore had been mined, and the bulk of the remaining ore was of low grade or contained so much zinc that it was penalized at the smelter. About 1896 the Alta mine was closed because it had reached a depth below which mining through adits and winzes was impractical. The Wickes smelter was then sold, dismantled, and moved to East Helena.

About 1900, interest in the copper veins near Corbin in the Wickes district started a minor boom. Several companies were organized to explore for copper, but the deposits found were small, and the boom ended during the panic of 1907 (Knopf, 1913, p. 108).

Since 1900 very little exploration has been done and mining has been carried out mostly by small companies, individual mine owners, or lessees with limited capital and little, if any, technical help. Much of the ore has come from easily accessible unmined parts of older mines or has been obtained by reworking dumps and tailings piles. The rise of metal prices during the two World Wars and in the twenties stimulated some activity.

After the increase in the price of gold in 1933, dredges operated on Prickly Pear and Clancy Creeks in the Clancy district, and many individuals worked placers on the smaller creeks. Work continued until 1947, except during the war years 1942–45 (Lyden, 1948, p. 42–44).

Uranium was discovered near Clancy and Boulder in 1949, and a small uranium boom started, but the deposits were found to be small or low grade, and only a few ore shipments were made.

PRODUCTION

Ores produced in the quadrangle have been principally valuable for their silver content, and, to a lesser extent, lead. Many contain as much zinc as lead, but the amount of zinc in the ore is usually not recorded because it is not paid for at the lead smelter. Selective flotation is required to separate the galena and sphalerite, but this process has not been used extensively in the area. Many veins, especially those in the vicinity of Rimini, contain much arsenic in the form of arsenopyrite, and such ore is penalized at the East Helena smelter. Much of the arsenopyrite has been sorted from the ore and either thrown on the dumps or left in the stopes.

Production [3] of metal from the quadrangle is impossible to determine accurately because of incomplete records, especially before 1901, and because the unorganized mining districts overlap quadrangle boundaries. However, most of the more productive mines in six mining districts are within the quadrangle. The six districts are most frequently called the Rimini (Vaughn), Clancy, Wickes (Colorado), Amazon, Boulder, and Cataract Creek districts (see list of mines, pl. 1). Available production statistics are given in table 9a.

Reliable production data prior to 1904 are not available, but old estimates (from company files) of production from six of the larger mines total about $55 million. The production between 1904 and 1950 from the six mining districts, in terms of recovered metals, was a little more than 241,000 ounces of gold, 8,647,000 ounces of silver, 58,945,000 pounds of lead, 32,107,000 pounds of zinc, and 7,706,000 pounds of copper; the total having a gross value at the time of production of over $23,478,000 (U.S. Geol. Survey, 1901–1923; U.S. Bur. Mines, 1924–1950). About $80 million seems to be a reasonable minimum figure for the total value of metal produced from the six districts. This estimate credits all of the many small mines that were actively worked before 1900 with a total production of only about $1 million, a figure that probably is too low.

VEINS

Almost all the mineral deposits that have been mined or explored in the quadrangle are in veins. Two types of veins are distinguishable; they are called quartz veins and chalcedony veins in this report, depending on which mineral is prevalent. The two types are distinct-

[3] Unless otherwise indicated, all specific production data in this report are from U.S. Geol. Survey, 1904–1923; U.S. Bur. Mines, 1924–50; or were furnished by the U.S. Bur. Mines.

TABLE 9.—*Recorded production of metals from mining districts in the Jefferson City quadrangle, Mont.*

[Compiled from U.S. Geological Survey (1904-23) and U.S. Bureau of Mines (1924-50) unless otherwise indicated]

	Value (when produced)	Gold (ounces)	Silver (ounces)	Lead (pounds)	Zinc (pounds)	Copper (pounds)
Rimini district:						
Before 1900	[1] $6,000,000					
1907–50	1,474,000	8,340	415,900	3,440,500	465,200	90,560
Clancy district:						
Lump Gulch:						
Before 1908	(2)		[3] 3,000,000			
1908–50	717,000					
Warm Springs area	[4] 1,000,000					
Placers	3,122,000	[5] 57,614				
Wickes district:						
Before 1900	[6] 40,500,000					
1904–50	5,850,470	18,210	2,530,897	20,345,691	7,082,174	3,243,865
Cataract Creek, Boulder, and Amazon districts:						
1904–50 [7]	12,314,289	115,800	5,308,000	34,610,000	24,479,000	4,317,000
Total	$70,977,759	199,964	11,254,797	58,396,191	32,026,374	7,651,425

1 Based on estimates quoted by Pardee and Schrader (1933, p. 346).
2 Unrecorded; includes most of district production.
3 Based on conservative estimates of stoped area, width of vein and grade of ore for Free Coinage (35), Little Nell (36), King Solomon (39), and Liverpool (west of quadrangle) mines.
4 Stone (1911, p. 88).
5 Lyden (1948, p. 42–44) quotes this figure. At $35 an ounce this gold would be valued at only $2,016,490. Lyden's figure may have been incomplete.
6 Alta (67), Gregory (63), and Minah mines only.
7 Includes some production from outside district, 1912–15.

ly different in mineralogy and appearance and are easily distinguishable in the field.

Quartz veins are tabular bodies, predominantly of coarsely crystalline quartz, in zones of sheared and intensely altered batholithic and prebatholithic rocks. Some are simple structures; others are complex networks of vein material. The word "veins" as used herein may thus include many veins and veinlets and also the altered wallrock that separates them. The veins contain varying amounts of sulfide minerals, not only intermixed with the quartz, but also in the adjacent altered rock; in fact, parts of a quartz vein may be made up almost entirely of sulfides with little or no quartz gangue. In places tourmaline is the chief constituent of large massive veins or of many small veinlets; it is generally intergrown with quartz and some pyrite. Chalcedony is not uncommon in quartz veins, but it is a minor constituent only, definitely younger than the quartz and sulfides.

Chalcedony veins consist predominantly of chalcedony and microcrystaline quartz. The veins occur singly or in groups in batholithic rocks that have been repeatedly brecciated and silicified along steeply dipping fractures, and they commonly have prominent, reeflike outcrops. Wallrocks around the chalcedony veins are altered, but the alteration differs somewhat from the alteration adjacent to quartz veins. The chalcedony veins contain only minor amounts of sulfide minerals, and for this reason, few have been explored and little is known about them. In recent years some chalcedony veins were found to be radioactive, and a few have actually produced uranium ore; uranium mineralization was not, however, confined to the chalcedony veins, but occurred in some of the quartz veins as well.

In a few veins, chalcedony and coarsely crystalline quartz are about equally abundant; such veins have been distinguished on plate 1 as quartz-chalcedony veins. Some may represent a stage of vein formation between the quartz vein and chalcedony vein types, but others are probably quartz veins along which there was fracturing and later deposition of chalcedony.

Many veins, particularly the quartz veins, contain stringers of one or more primary carbonate minerals, and some consist almost entirely of carbonate minerals. The stringers cut both quartz and sulfide minerals and are younger than either.

Most of the veins are oxidized at the surface, and, rarely, oxidation has reached depths as great as 400 feet. Some quartz veins crop out as iron-stained siliceous boxworks, and the prominent, reeflike outcrops of chalcedony veins are thoroughly iron stained. Some of the ore produced in the early days of near-surface mining consisted of secondary minerals formed from the oxidation of sulfide minerals rather than the sulfide minerals themselves. Secondary uranium minerals have been identified in radioactive parts of veins.

Because the chalcedony veins are barren of sulfide minerals or nearly so, they were not included in investigations of the ore deposits of the Boulder batholith by Knopf (1913) and Billingsley and Grimes (1918). The veins called quartz veins in this report have, however, been of considerable economic interest, and they have been described and interpreted in different ways.

Knopf (1913, p. 42–61) classified the veins in and around the batholith primarily on the basis of age, whether older or younger than the Tertiary volcanic rocks. The group that he considered older was characterized by the presence of tourmaline and sericite and was divided according to assemblages of metals for which the ore was chiefly valuable. This system is of limited usefulness in the Jefferson City quadrangle because veins in Knopf's two age groups have more similarities than differences and because in only two places, both of which are beyond the borders of the quadrangle, can Knopf's age relations be demonstrated with certainty. Furthermore, Knopf uses the general term "tourmalinic" for all the veins in the older group, although he recognized that in many tourmaline is a very minor constituent and in others tourmaline is absent.

Billingsley and Grimes (1918, p. 284–361) referred the ore deposits in and around the Boulder batholith to six "phases" of mineralization, which they considered to be genetically related to three periods of igneous activity. All of the veins in the Jefferson City quadrangle would belong in the aplite phase of their granite period. They state (p. 304–318) that the ore deposits were derived from and grade into nearby aplite dikes. In places pegmatitic parts of large alaskite bodies or small pegmatitic segregations in the main stage rocks of the batholith have miarolitic cavities containing quartz, tourmaline, and pyrite, but none of the hundreds of veins that were mapped and examined during the course of the fieldwork for this report grade into aplite, alaskite, or pegmatite. Furthermore, the distribution and structure of the quartz veins and of most bodies of alaskite are notably different.

QUARTZ VEINS

The quartz veins are characterized by: (1) abundant quartz; (2) abundant and ubiquitous pyrite; (3) galena, sphalerite, arsenopyrite, and chalcopyrite in amounts that differ greatly from place to place in any one vein and from one vein to another; (4) wallrocks intensely altered, mostly to sericite and clay minerals; and (5) inconspicuous outcrops. They are in zones of sheared and altered rock, nearly all of which dip steeply and strike within 20° of east (fig. 30). A few strike N. 40°–60° E. Many of the mineralized shear zones can be traced for half a mile or more, and some extend a few miles along strike. The longest zone in the quadrangle is the Comet–Gray Eagle shear zone in the southwestern part; other long shear zones are the Bluebird–Mount Washington zone in the Wickes district, the Eva May zone in the Cataract Creek district, and the Lee Mountain–Valley Forge zone in the Rimini district. The most productive shear zone—that which includes the Alta mine in the Wickes district—probably extends from the eastern side of Alta Mountain westward beneath the cover of Tertiary volcanic rocks to the Occidental Plateau. All these structures are described in detail in the district and mine descriptions.

STRUCTURE

The fractured and altered zones range in complexity from a single joint or a few closely spaced parallel or nearly parallel joints to wide and complex shear zones. In some of the larger and more persistent zones the rock is fractured and altered across widths of several tens of feet, and the Comet–Gray Eagle zone is as much as a few hundred feet wide. Although the zones are continuous, individual joints or faults within the zones can be traced for only short distances. In many places the fractures in a zone are not parallel but tend to merge and branch in an anastomosing pattern.

The veins within these shear zones were formed largely by replacement of the rock adjacent to fractures by quartz, sulfide minerals, and carbonate minerals; the structure of a vein, therefore, reflects the original structure of the fracture system. Some veins consist simply of a few parallel stringers or veinlets along joints separated by altered wallrock. Others are much more complex. Where fractures were closely spaced, the different strands of the vein have merged by replacement of the intervening wallrock, but they are still distinguishable by differences in mineralogy or by selvages of wallrock between them. Along strike, individual veins die out where their controlling fault or joint dies out, but other subparallel veins continue along the shear zone or vein zone. Regardless of the complexity of the controlling fracture system, nearly all the veins have sharp walls and only a few grade into their wallrocks.

Along some veins small veinlets diverge from the strike of the main vein to form a complex horsetail structure. The branches are commonly narrow and few in number along any one vein. An interesting exception is the vein at the Baltimore mine (89), where horsetail structure is unusually well developed in a zone as much as 200 feet wide and possibly more than 500 feet long (pl. 18). The divergent veins within this zone are strong and up to several feet wide.

MINERALOGY

Quartz is by far the most abundant mineral in the veins, and in many places it constitutes almost the entire vein. It ranges in color from clear to gray and in grain size from very coarse to fine. Most of it is coarsely crystalline and milky white from a multitude of very small, closely spaced fluid inclusions.

Pyrite is the second most abundant mineral in the veins, and in some places pyrite and quartz together compose the entire vein. Pyrite occurs largely as grains disseminated in the wallrocks and in the quartz, as massive bodies that have replaced wallrock or earlier vein minerals, and as minor fillings of open fractures. Crystals range from about 6 inches across to submicroscopic and from euhedral to anhedral. All the pyrite contains numerous inclusions, mostly of wallrock minerals or adjacent minerals. Many crystals are zoned with inclusions; the outer zones contain more than the inner zones, probably because there was less time for complete replacement of adjacent minerals in the outer, younger zones before deposition of pyrite ceased. A little pyrite is pseudomorphic after marcasite.

In places tourmaline is the chief constituent of large massive veins. It is usually intergrown with quartz and, to a lesser extent, pyrite. In addition, tourmaline and a little quartz with or without potassium felspar and pyrite form many small veins up to about 4 inches wide. Most tourmaline occurs as fine black to dark-green needles intergrown into a tough, feltlike mass.

The primary carbonate minerals that are a late constituent of many veins are largely members of the calcite-dolomite and dolomite-ankerite series. Dolomite containing 10 to 20 percent iron is most common. Manganese carbonate was not identified, but its presence is indicated by manganiferous gossans.

Argentiferous galena is the chief ore mineral in the quartz veins. Together with sphalerite and lesser amounts of quartz and pyrite, it forms large massive replacement-type ore bodies; it also occurs as disseminated grains or small masses in the wallrock beside massive ore bodies. Apparently pure masses of galena yield, on analysis, several ounces of silver per ton; rarely, a very small amount of tetrahedrite can be seen in polished sections of galena.

Sphalerite is very common in the veins. It is nearly everywhere associated with galena, pyrite, and quartz in ore bodies that have replaced wallrock along tight fractures. It rarely was deposited in open fractures and is not disseminated in the wallrocks. It ranges in color from very dark red to light yellow or light green. The dark sphalerite contains considerable exsolved chalcopyrite and is characteristic of some of the larger veins.

Arsenopyrite is a lesser constituent of many veins, but in some it is abundant enough to contribute a few percent arsenic and thus to be detrimental to the ore. The arsenopyrite is mostly in euhedral crystals intergrown with quartz and deposited in open fractures.

Several minerals are common as minor constituents of the quartz veins. Chalcopyrite is by far the most widespread; small amounts of it occur in most ore, but it is abundant only locally. Small crystals or grains of tetrahedrite are generally associated with chalcopyrite. Stibnite, bornite, cosalite, enargite, chalcocite, ruby silver, boulangerite, bournonite, and alabandite have been found at or reported from mines in the quadrangle.

Oxidation of the vein minerals has formed a number of secondary minerals, some of which were abundant enough near the surface to be shipped as ore in the early days of mining. The most common secondary minerals are, in order of decreasing abundance, goethite and lepidocrocite, hematite, jarosite, cerussite, malachite, and azurite. Secondary minerals identified from a few localities include cerargyrite and the lead minerals pyromorphite, anglesite, and beudantite. Meta-autunite, metatorbernite, and other less common secondary uranium minerals have been found in some quartz veins. Manganese oxide minerals, including pyrolusite and psilomelane, and iron oxides are particularly abundant in quartz veins in an area east of the Occidental Plateau near the head of Clancy Creek. Parts of the veins in the Blackbird group (53) and at the General Harris mine (50) contain about 20 percent manganese and 15 percent iron. Manganese and iron oxides are abundant on the dumps of other mines nearby.

MINERAL ASSEMBLAGES

The common primary minerals in the quartz veins tend to be associated in groups or assemblages containing only a few minerals. These assemblages are:

1. Galena, sphalerite, pyrite, and quartz
2. Arsenopyrite and quartz
3. Quartz and tourmaline
4. Quartz, pyrite, and chalcopyrite with or without tetrahedrite
5. Primary carbonate minerals and some quartz and pyrite.

The proportions of the minerals in any assemblage differ from place to place, but the minerals listed first in the assemblages above are usually the most abundant, except that sphalerite may predominate over galena locally.

In many veins the mineral assemblages tend to be grouped in separate layers. Large segments of some veins contain the minerals of one assemblage almost exclusively, and a few entire veins are made up of the minerals of one assemblage with only minor amounts of other minerals. In some places where veins made up of different mineral assemblages merge, the minerals are mixed and intergrown; but even so, the different assemblages usually can be recognized.

Most of the mineral assemblages are found wherever quartz veins are abundant in the quadrangle, but a few seem to be more concentrated in some areas than in others. The arsenopyrite-quartz assemblage, although fairly widespread, is notably common in the Rimini district and at the Bluebird (43) and Minah (49) mines in the Wickes district. The quartz-tourmaline assemblage is common only in the Rimini district, where a few veins contain little else, and at the Bluebird mine in the Wickes district. The quartz-pyrite-chalcopyrite assemblage is found in many veins but is most typically developed near Corbin in the Wickes district in an area of a few square miles east and northeast of Alta Mountain. In a few of these veins, quartz, pyrite, and chalcopyrite are virtually the only minerals present. The primary carbonate minerals are abundant near the ends of the Comet–Gray Eagle shear zone and are sparse in the middle of the zone.

PARAGENESIS

The paragenesis of the vein minerals does not involve a complex sequence of individual minerals but rather a simple sequence of the distinctive mineral assemblages. Few veins contain the entire sequence; however, the mineral assemblages can usually be identified, and the time relations among assemblages are the same nearly everywhere. This sequence from oldest to youngest, is:

1. Tourmaline-quartz-pyrite
2. Pyrite, coarse-grained
3. Galena-sphalerite-pyrite-quartz
4. Arsenopyrite-quartz
5. Pyrite, fine-grained (absent in many places)
6. a. Quartz, coarse-grained, microcrystalline, or chalcedony
   b. Chalcopyrite (or other minor copper minerals)
   c. Quartz, fine-grained, microcrystalline, or chalcedonic
7. Carbonate minerals, fine-grained to microcrystalline quartz or chalcedony, and minor pyrite.

Reversals of the sequence are rare. They have been recognized only in a few quartz-chalcedony veins and sulfide-bearing chalcedony veins. Those at the Lone Eagle mine (42) and the Free Enterprise mine (90) have been studied in detail (Wright and others, 1957).

ORE BODIES

Ore minerals are scattered throughout large parts of most veins, but only locally are they sufficiently concentrated to form ore bodies. Little is known about the limits and shape of most of the ore bodies, and even less is known about their internal features. Most ore bodies were found at the surface and were sporadically worked on a small scale during a number of years by miners who kept very few records or maps. So far as we can determine, the Comet (100) and Gray Eagle (99) are the only mines in the area in which geology was systematically mapped during operation; and even there, very little is known of the geology in the older workings or in the stopes. In many mines examined during the course of this study, the areas formerly occupied by ore bodies are inaccessible because of caved ground, and only the less valuable parts of the veins are exposed in drifts and crosscuts.

The ore bodies range in size from shoots a foot or two wide and a few tens of feet long within single veins to large, complexly fractured and mineralized parts of altered zones several hundred feet long and as much as 150 feet wide, containing several large rich ore shoots. The largest known ore bodies are in the Mount Washington (46), Alta (76), and Comet (100) mines. The Mount Washington ore body is at least 2,000 feet long and extends to a depth of at least 1,000 feet. The Alta ore body, the most productive in the quadrangle, is about 1,600 feet long and was mined to a depth of about 1,400 feet below the outcrop. It contains three major shoots of rich ore. Most ore bodies, however, are only a few hundred feet long. Little is known of their overall vertical extent because few have been worked below adit levels and their tops are eroded.

Ore bodies apparently consist of overlapping lenses of ore separated by low-grade or barren layers of wallrock or vein minerals. The greatest width of individual ore shoots in the Comet mine (100) was 25 feet, but neither the vertical nor the horizontal extent of single ore shoots is known.

CHALCEDONY VEINS

The chalcedony veins are characterized by abundant chalcedony and microcrystalline quartz, minor amounts of sulfide minerals, wallrocks altered partly to clays, and prominent reeflike iron-stained outcrops. They are of little economic importance.

Most chalcedony veins consist of many layers and stringers of chalcedony and microcrystalline quartz between walls that have been altered across a zone as much as 150 feet wide. Many of the veins are only a few inches wide, and probably most are less than 10 feet across. Most zones consist of one or more persistent veins of dense chalcedony and fine-grained quartz bordered by many smaller veinlets of the same material cutting the wallrock in an anastomosing pattern to form a crude net of siliceous veinlets. Some of the chalcedony vein zones lack the border of anastomosing veinlets and consist of only a few closely spaced chalcedony veins. Other vein zones lack the stronger chalcedony veins and are made up of only a zone of anastomosing veinlets; still others seem to be nothing more than a linear zone of altered rock.

Some veins are only a few tens of feet long and change strike within a short distance, but many others are very persistent. One strong zone of chalcedony veins extending northeastward from the center of sec. 35, T. 8 N., R. 4 W., is nearly continuous for a length of 6 miles and extends 2 miles beyond the edge of the quadrangle.

Nearly all the chalcedony veins are in the batholithic rocks. They are clustered in a northern area and a southern area (pl. 3); the few outside these areas are mostly in the vicinity of Chessman Reservoir near Rimini. The southern area is roughly bounded on the east by the Boulder Valley, on the north by the Comet-Gray Eagle shear zone, and on the west by Big Limber Gulch; the area extends 4 miles southward beyond the limits of the quadrangle (Becraft and Pinckney, 1961). The northern area extends from the northeastern end of the roof remnant northwest of Corbin, northward to Lump Gulch and eastward and northeastward about 2 miles beyond the edge of the quadrangle (Smedes, 1962a).

In the southwestern part of the quadrangle the veins have diverse strikes, but a few miles to the east, in the alaskite belt (especially in secs. 17, 18, 19, and 20, T. 6 N., R. 4 W.), almost all the veins trend N. 60° to 70° E., and near the Comet-Gray Eagle zone they trend eastward, parallel to the zone. Within the quadrangle, all the more persistent veins in the northern and southern areas strike about N. 65° E. and are parallel to many of the alaskite and quartz-latite dikes. However, near the east edge of the quadrangle many of the veins in the northern area swing more to the east, and in the Clancy quadrangle all the large veins trend eastward for about 2 miles and die out (Smedes, 1962a).

The chalcedony veins are distinctly different from the quartz veins in mineralogy. They consist almost entirely of chalcedony, microcrystalline quartz, opal, and, in places, pyrite and barite. Locally at least four generations of chalcedony and microcrystalline quartz, separated by intervals of fracturing or brecciation, can be distinguished (Roberts and Gude, 1953a, p. 73). Chalcedony in radiating fibrous aggregates characteristically fills open spaces and has botryoidal structure. Much chalcedony probably has recrystallized to microcrystalline quartz; this is indicated by relict botryoidal structure in otherwise massive microcrystalline quartz. Quartz in such masses commonly extinguishes through a rotation of from 20° to 70°. The microcrystalline quartz is mostly gray or brown but ranges from white to black. The darker shades are due to a few percent of finely divided sulfide minerals, largely pyrite. The brown shades are common in outcrops of veins and are largely due to iron oxides derived from sulfide minerals. Pyrite is common as very small crystals scattered sparsely in chalcedony and microcrystalline quartz or in altered wallrock.

Other minerals are sparse in the chalcedony veins and vein zones. Minor amounts of sulfide minerals have been found or reported, including galena, sphalerite, arsenopyrite, ruby silver, argentite, molybdenite, chalcopyrite, and cinnabar. A small amount of silver has been produced from a chalcedony vein at the Free Enterprise mine (90), near the south edge of the quadrangle, but no concentrations of base metals have been found.

Small uranium deposits, a few of moderately high grade, have been found in the chalcedony veins and vein zones. A comprehensive study of the mineralogy of some of these deposits has been made by Wright and others (1957). Uraninite was identified in ore at the W. Wilson mine (just east of the quadrangle) and in tiny stringers at the G. Washington mine (40) in the Clancy district. Local pods of uraninite at the Free Enterprise mine (90) are associated with small concentrations of silver-bearing minerals.

Secondary uranium minerals are more abundant. They are concentrated in pods, line fractures and are disseminated in and adjacent to the veins. Meta-autunite, metatorbernite, phosphuranylite, uranocircite, voglite, and rutherfordine have been identified. In the Clancy district, secondary uranium minerals have replaced pitchblende in place. Secondary minerals line fractures and are disseminated in the wallrocks indicating some redistribution of uranium during weathering, but no substantial migration of uranium has taken place.

QUARTZ-CHALCEDONY VEINS

The quartz-chalcedony veins are characterized by about equal quantities of coarsely crystalline quartz and chalcedony, either intermingled or segregated. Most of the veins are on the ridge between Big Limber Gulch and High Ore Creek, on the ridge between Beavertown and Spring Creeks, or in the northeast corner of the quadrangle.

The quartz ranges in grain size from very fine to coarse subhedral crystals typical of the quartz veins, and in color from milky to light gray, almost clear. The chalcedony ranges in color from light gray to dark gray, almost black. Sulfide minerals are commonly associated with the coarse quartz parts of the veins but are scarce or lacking in the microcrystalline quartz and chalcedony. The most common sulfide mineral is pyrite; galena and sphalerite are locally abundant, and chalcopyrite and tetrahedrite occur in a few places.

The Little Nell vein is typical of many quartz-chalcedony veins. At the Little Nell mine (36) the vein consists principally of milky quartz grains or crystals a few millimeters in diameter associated with pyrite, galena, and sphalerite. About 1½ miles northeast, the vein is predominantly microcrystalline quartz and chalcedony and contains no sulfide minerals. Farther east at the Liverpool mine, a short distance east of the quadrangle boundary, the vein is again predominantly quartz and contains sulfide minerals. From this point eastward to the end of its outcrop area, the vein contains mostly chalcedony and carbonate minerals.

The change from predominantly coarse-grained quartz to predominantly chalcedony also takes place vertically. The High Ore vein along its outcrop in secs. 2, 3, and 10, T. 6 N., R. 5 W., consists of a few large veins and many veinlets of chalcedony in altered quartz monzonite. About 900 feet beneath the land surface, where it is cut by the High Ore crosscut (88), the vein consists of fine- to coarse-grained gray to white quartz and contains pyrite, galena, and sphalerite.

A quartz-chalcedony vein at the Lone Eagle mine (42) in the Wickes district was prospected for sulfides and also explored for uranium. Pyrite, galena, sphalerite, minor amounts of chalcopyrite and argentite, and a little pitchblende are associated with a gangue of crystalline quartz, some microcrystalline quartz and chalcedony, and carbonate minerals. The pitchblende is closely associated with microcrystalline quartz that is younger than the sulfide minerals and crystalline quartz (Wright and others, 1957, p. 122).

WALLROCK ALTERATION

The first reference to rock alteration in the area was made by Winchell and Winchell (1912), who briefly described the alteration of granitic rock at the Bluebird mine west of Wickes. Knopf (1913) described the alteration of quartz monzonite at some of the mines in the quadrangle, and he summarized the main differences in wallrock alteration produced by the "younger" and "older" veins in his classification of the ore deposits. D. Y. Meschter made the first detailed petrographic study of rock alteration in the W. Wilson mine, just east of the map area, and observed the symmetric arrangement of the alteration zones adjacent to the chalcedony veins. Other detailed investigations were made by Wright and others (1954, 1957), Wright and Bieler (1953), and Wright and Shulof (1957) in the W. Wilson, Lone Eagle (42), Gray Eagle (99), G. Washington (40), and Free Enterprise (90) mines in connection with the investigation of uranium deposits. Roberts and Gude (1953a, b) mention the alteration of quartz monzonite west of Clancy and at the Free Enterprise mine.

In the Jefferson City quadrangle we collected suites of altered rock, including specimens from the vein outward to the least altered rock available, from outcrops, prospect pits, and the relatively few accessible mines. Only a few suites that included specimens representative of the entire width of altered rock adjacent to a single vein were obtained for two reasons: (1) The entire width of the alteration zone was exposed in very few of the accessible mines, and (2) because most of the veins in the quadrangle are complex structures, the alteration zones are complicated by overlap of adjacent alteration envelopes, faulting, reopening of vein channels and superposition of progressive alteration effects, and telescoping of zones.

Only a few usable specimens of Elkhorn Mountains volcanics and alaskite were obtained, and thus only the alteration of quartz monzonite and granodiorite was studied in detail. A suite from the Bunker Hill mine (13) in the Rimini district is typical of the alteration adjacent to the quartz veins, and a suite from the G. Washington mine (40) in the Clancy district is typical of that adjacent to many of the chalcedony veins. Observations from these suites were most heavily drawn upon for the interpretation of alteration sequences.

Based on these studies, several generalizations can be made about wallrock alteration adjacent to veins, regardless of rock type or vein type:

1. Alteration zones are symmetrically arranged around most well-defined veins.
2. Ideally, the zones outward from a quartz vein are a sericitic zone, an argillic zone, and a chloritic zone. Adjacent to most chalcedony veins the sericitic zone is missing but the argillic and chloritic zones are present.
3. Sulfide minerals partly replace sericitized wallrock; no vein sulfides were observed in argillic, chloritic, or unaltered wallrocks.
4. Reversals in pattern and crosscutting relations among the zones were not observed.
5. The original rock minerals and alteration products adjacent to uranium-bearing veins are the same as those adjacent to veins without uranium.

QUARTZ MONZONITE ADJACENT TO QUARTZ VEINS

The following ideal set of subzones outward from a quartz vein was determined from observations on some typical alteration patterns in quartz monzonite:

- Sericitic zone
  - Silicified subzone (minor)
  - Sericite-pyrite subzone
- Argillic zone
  - Kaolinite-rich subzone
  - Montmorillonite-rich subzone
- Chloritic zone

The silicified subzone of the sericitic zone is locally present and in some places contains abundant black tourmaline. The boundary between a vein and the sericitic zone is difficult to locate accurately where the silicified subzone is present; but where silicified rock is absent, the contact is easily located and is generally irregular over a few inches. Sericitized and pyritic rock is greenish gray and is soft compared to the siliceous vein.

The boundary between the sericitic and argillic zones is generally subparallel to the vein and is gradational over a distance of a fraction of an inch to a few inches. It is marked by a change from greenish-gray lustrous sericite-pyrite-quartz rock to gray-white clayey material that still has original rock textures and contains original potassium feldspar in many places.

The boundary between argillic and chloritic zones is commonly gradational over about 1 foot. It is marked by the transition from friable grayish argillic rock to firm gray quartz monzonite in which plagioclase is generally clouded and mafic minerals are dulled and greenish. The boundary between the chloritic zone and unaltered rock has not been observed in any of the mine workings, but sampling at the surface indicates that it is broadly gradational over a distance of many feet from rock in which the mafic minerals are abundantly chloritized by hydrothermal solutions to rock wherein the mafic minerals are sparsely chloritic, possibly due to deuteric reactions.

The effect of alteration on the original rock-forming minerals and the generation and persistence of alteration products are shown on table 10 and are illustrated by a suite of samples from the Bunker Hill mine (13) near Rimini. Four samples, collected across a width of about 20 feet adjacent to a tourmaline-rich vein 4 feet wide, included (1) chloritized rock, (2) chloritized and partly argillized rock, (3) intensely argillized rock, and (4) thoroughly sericitized rock slightly replaced by vein material. Table 11 gives chemical analyses, norms, modes, and specific gravities of the four samples.

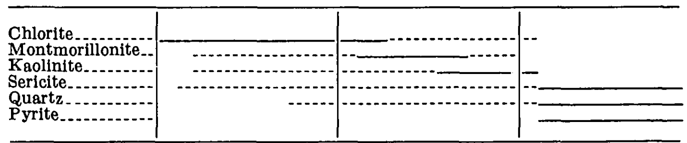
TABLE 10.—*Alteration of minerals adjacent to quartz veins in quartz monzonite and relative persistence of the products*

[Italicized products are index minerals in each zone]

Unaltered rock	Zone		
	Chloritic	Argillic	Sericitic
K-feldspar	Unaltered to slightly clay dusted.	Clay-dusted to partly altered to fine-grained *kaolinite*.	Entirely altered to *sericite* and *quartz;* outlines destroyed.
Plagioclase	Clay-dusted to partly argillized; incipient sericite along cleavages and fractures.	Altered to *montmorillonite* and kaolinite, sericite, quartz, some epidote, calcite; many outlines destroyed.	Clays entirely altered to *sericite* and *quartz*.
Biotite	Partly altered to *chlorite*, illite, kaolinite, and ilmenite, magnetite.	Altered to illite, *montmorillonite*, *kaolinite*, chlorite, sericite, ilmenite, and leucoxene; outlines destroyed.	Muscovite or *sericite*, *pyrite*, *quartz*, and some leucoxene.
Hornblende	Altered to *chlorite*, magnetite, ilmenite, epidote, sphene, calcite, quartz, and clays; outlines partly destroyed.	Ilmenite, calcite, leucoxene, epidote, illite(?), *montmorillonite*, quartz, and chlorite.	*Sericite*, *pyrite*, quartz and leucoxene.
Quartz	Unaltered	Unaltered to slightly replaced by kaolinite.	Partly recrystallized and intergrown with sericite; original outlines destroyed.
Accessory minerals.	Unaltered zircon, apatite, magnetite, ilmenite, and sphene.	Ilmenite and sphene partly altered to leucoxene.	Fe-minerals altered to *pyrite* and leucoxene; zircon and apatite unaltered.

Zonal range of alteration products

[Solid lines indicate range of abundant formation; dashed lines indicate minor amounts of the products]



MINERALOGICAL CHANGES

Chloritic zone.—In the chloritic zone plagioclase is moderately to heavily clay dusted and incipiently sericitized, especially along cleavages and certain zones (fig. 34, *A–D*). Hornblende is almost entirely altered to chlorite, magnetite, ilmenite, epidote, sphene, calcite, nontronite(?) and quartz. Biotite is partly altered to magnetite (or ilmenite), pyrite, chlorite, illite(?), kaolinite, and a small amount of pale-brown isotropic material ($N=1.54$) associated with the illite(?). A peculiar alteration feature of many biotite grains is the change in color of the maximum absorption. From brown black it becomes medium red brown with the onset of chloritization; this is especially well developed in the Crescent mine (20) in the Rimini district. Complete bleaching in narrow streaks parallel to the cleavages is due to the formation of illite(?). Potassium feldspar, quartz, and the accessory minerals appear unchanged. Veinward in the chloritic zone, argillization of the feldspars increases until plagioclase is much altered to clays and some sericite, and potassium feldspar is slightly clay dusted. Samples B249 and B248 in table 11 are from the chloritic zone; sample B248 is from near the boundary between the chloritic zone and the argillic zone.

Argillic zone.—In the early phase of the argillic zone, the plagioclase is entirely replaced by very fine grained (0.003 mm) felted clay, equant-grained clays, and sericite streaks and wisps that reflect former cleavages and zones (fig. 34, *E* and *F*). The feltlike clays are too fine grained for optical determination, but the birefringence is strong. Clay staining and differential thermal and X-ray analyses indicate that the clay is mostly montmorillonite. Toward the vein the equant-grained clays increase in grain size (0.005–0.01 mm) but the birefringence is relatively low. The equant-grained clays have the indices and birefringence of kaolinite, and its presence in this phase is confirmed by X-ray and differential thermal analyses. In places networks, streaks, and wisps of clays with higher birefringence persist in the midst of the kaolinite masses nearest the vein. The potassium feldspar encloses clay patches that represent former anhedral to subhedral plagioclase grains but otherwise shows little change. Hornblende relicts consist of mixtures of ilmenite, leucoxene, nontronite(?), epidote, illite(?), and small amounts of chlorite, kaolinite, quartz, and sericite. Unit muscovite and illite(?) pseudomorphs after biotite are common in places. Near the veinward margin of the zone hornblende relicts are difficult to identify, but biotite relicts consist of muscovite shreds coated with leucoxene and magnetite. Titaniferous accessories are partly changed to leucoxene, but apatite and zircon remain unaltered. Sample B247 in table 11 is from the argillic zone.

Sericitic zone.—The sericitized rock consists largely of quartz, very fine grained (0.01–0.1 mm) sericite, and small amounts of pyrite. Quartz and sericite are evenly mixed and intergrown, and the pyrite is randomly scattered through the rock. Accessory apatite and zircon are not altered. Near the vein the sericite is considerably coarser (a maximum of about 2 mm long) and radiate, stellate, feathery, and wavy forms are intergrown and anhedral quartz and acicular to stubby tourmaline prisms (fig. 34, *F* and *G*). Pyrite cubes (as much as 2 or 3 mm in width) are sparse, but anhedral masses of pyrite as much as half an inch across are common. The pyrite replaces sericite, quartz, and tourmaline and is in turn cut and replaced by ore minerals. Sample B246 in table 11 is from the sericitic zone.

TABLE 11.—*Analyses, norms, modes, and specific gravity of altered quartz monzonite adjacent to a quartz vein (Bunker Hill mine)*

[Chemical analyses by L. N. Tarrant and L. Trumbull]

Laboratory No.	B249 [1]	B248 [2]	B247 [3]	B246 [4]
Chemical analyses				
SiO_2	66.05	66.13	68.42	64.44
Al_2O_3	14.80	15.22	16.88	14.37
Fe_2O_3	1.52	1.84	1.68	.14
FeO	2.71	2.37	.50	[5] 8.16
MgO	1.58	.74	.55	.46
CaO	2.68	2.16	.30	.03
Na_2O	2.57	2.57	.29	.07
K_2O	5.00	4.93	5.89	3.61
H_2O-	.28	.50	.71	.04
H_2O+	.83	.89	3.46	1.75
TiO_2	.52	.52	.62	.40
CO_2	.74	1.43	.04	.02
P_2O_5	.13	.14	.17	.00
S	--------	--------	--------	7.05
SO_3	--------	--------	--------	.24
MnO	.30	.32	.02	.03
BaO	.04	.06	--------	.01
Sp. Gr	2.68	2.64	2.27	2.85
Norms				
Apatite	0.34	0.34	0.34	------
Pyrite	--------	--------	--------	13.32
Ilmenite	1.06	.91	.61	.76
Rutile	--------	--------	.32	------
Magnetite	2.32	2.55	--------	------
Thenardite	--------	--------	--------	.43
Orthoclase	29.47	28.91	35.03	------
Sericite	--------	--------	--------	29.46
Albite	21.48	21.48	2.62	------
Anorthite	12.51	10.29	1.39	------
Hypersthene	7.66	4.21	--------	------
Enstatite	--------	--------	1.40	.80
Hematite	--------	--------	1.76	
Kaolinite	1.55	4.90	24.00	2.84
Corundum	--------	--------	--------	1.94
Quartz	22.20	23.58	42.54	49.38
Modes				
K-feldspar	31	29	32	------
Andesine	30	28	--------	------
Quartz	23	19	26	48
Biotite	4	4	3	------
Hornblende	3	--------	--------	------
Magnetite/leucoxene	1	1	2	1
Chlorite/illite	2	1	--------	------
Clays	4	14	36	------
Sericite	3	4	2	45
Pyrite	--------	--------	--------	4
Tourmaline	--------	--------	--------	2
Accessories	<1	<1	<1	<1

[1] Chloritic.
[2] Chloritic, partly argillic rock.
[3] Argillic rock.
[4] Pyritic-sericitic rock.
[5] Because of the presence of acid-soluble sulfides the ratio of FeO to Fe_2O_3 is not reliable.

CHEMICAL CHANGES

The chemical composition of the quartz monzonite changes as alteration becomes more intense (table 11). Most of the bases decrease in amount from the least altered to the most altered rock. From sample B249 to sample B248, the composition is changed only slightly; silica, aluminum, and carbon dioxide increase slightly and magnesium and calcium decrease slightly. Across the argillic zone from sample B248 to B247, the chemical composition and specific gravity change markedly. Total iron decreases substantially and magnesium decreases slightly; calcium, sodium, and carbon dioxide are removed. The specific gravity drops to a minimum. The relative increase in silica, aluminum, and water corresponds with the development of abundant clays in the rock. From sample B247 to sample B246 the increase in specific gravity is the result of the increase in iron and sulfur (as pyrite).

ALASKITE ADJACENT TO QUARTZ VEINS

The alteration of alaskite appears similar to the alteration of quartz monzonite, but because mafic minerals are virtually absent in alaskite and much of the plagioclase was altered to clay—apparently by late deuteric solutions—the chloritic zone and the argillic zone are difficult to recognize. Usually the first obvious alterations are the conversion of any biotite to chlorite and the replacement of the clay pseudomorphs of plagioclase by sericite. Nearer the vein the potassium feldspar is replaced by sericite and the original texture of the rock is destroyed. Accessory apatite and zircon are unchanged near the vein. Sericitized alaskite usually has less pyrite than sericitized quartz monzonite, probably because of the paucity of available iron from mafic minerals in alaskite. The alteration envelope adjacent to a vein that cuts both alaskite and quartz monzonite is considerably wider in the quartz monzonite than in the alaskite. This is well illustrated in the Eva May mine where alteration zones, easily recognized in quartz monzonite on crosscut walls, can hardly be seen with a hand lens adjacent to the same veins in alaskite (fig. 35).

GRANODIORITE ADJACENT TO CHALCEDONY VEINS

A suite of samples from the G. Washington mine (40) in the Clancy district illustrates the alteration adjacent to a chalcedony vein. Seven samples of granodiorite were collected across a width of about 9 feet adjacent to a chalcedony vein 2 feet wide. Sample B256 is virtually unaltered; samples B255 to B253 and are chloritized; and samples B252 to B250 are predominantly argillized (table 12). Sample B250 was in contact with an irregular chalcedony veinlet.

The petrography and mineral paragenesis for altered granodiorite in the G. Washington suite are similar to those of the chloritic and argillic rocks of the Bunker Hill suite. The following differences and special features are characteristic of wallrock alteration adjacent to chalcedony veins:

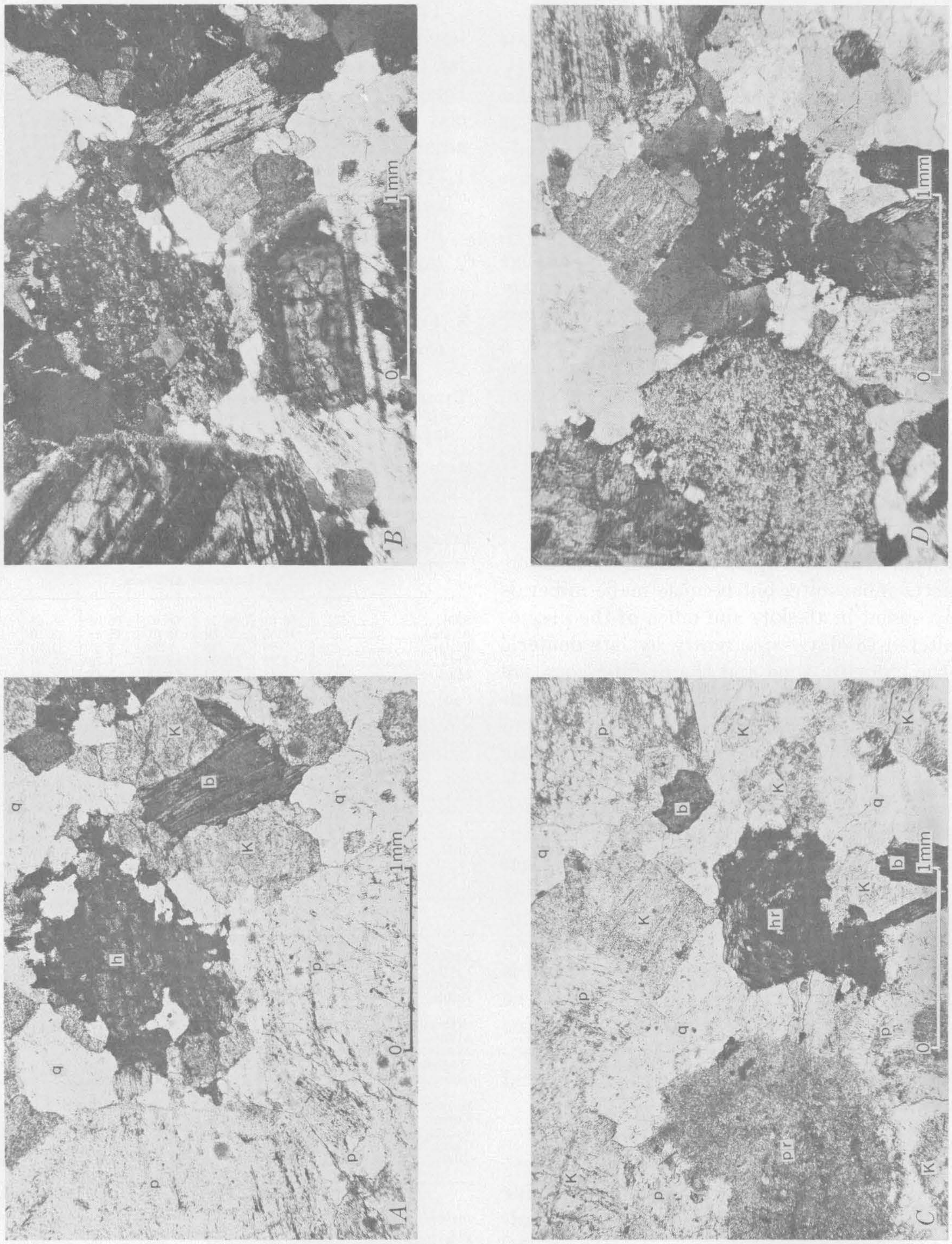
1. The sericitic zone is present adjacent to chalcedony veins only very locally. Argillized rock is commonly in contact with the veins.
2. Alteration envelopes are generally narrower than envelopes around quartz veins.
3. Original rock textures persist in altered rock adjacent to the veins.

TABLE 12.—*Analyses, norms, modes, and specific gravity of altered granodiorite adjacent to a chalcedony vein (G. Washington mine)*

[Samples are progressively more altered, from left to right, from virtually unaltered rock (B256) to argillized rock in contact with vein (B250). Chemical analyses by L. N. Tarrant and Jean Theobald]

Laboratory No.	B256	B255	B254	B253	B252	B251	B250
Chemical Analyses							
SiO_2	68.01	68.11	65.62	66.24	68.44	68.93	65.30
Al_2O_3	15.52	15.39	15.61	15.48	18.10	17.11	15.06
Fe_2O_3	.29	.26	1.24	3.57	1.70	3.21	8.85
FeO	[1] 2.95	[1] 2.60	[1] 3.22	[1] .79	.00	.00	.18
MgO	1.42	1.42	1.53	1.43	.43	.16	.07
CaO	2.69	2.46	2.80	2.62	.37	.11	.07
Na_2O	3.10	2.73	2.99	2.81	.38	.18	.18
K_2O	3.24	4.57	3.44	3.59	2.71	3.69	3.16
H_2O-	.22	.17	.27	.50	1.92	.77	.60
H_2O+	.72	.72	1.22	1.28	5.10	4.91	5.21
TiO_2	.48	.47	.51	.48	.55	.56	.47
CO_2	.02	.02	.03	.02	.01	.00	.01
P_2O_5	.10	.12	.17	.16	.05	.12	.23
S	.99	.71	1.14	.70	.01	.02	.02
MnO	.04	.04	.05	.04	.00	.01	.02
BaO	.01	.05	.04	.06	.04	.04	.04
Sp. Gr.	2.67	2.61	2.64	2.61	2.26	2.44	2.54
Norms							
Apatite	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Pyrite	1.92	1.13	2.16	1.31	-------	.12	.12
Ilmenite	.91	.91	.91	-------	-------	-------	.46
Rutile	-------	-------	-------	.48	.56	.56	.24
Orthoclase	18.90	27.24	20.02	27.24	16.12	21.68	18.90
Albite	26.20	31.44	25.15	23.58	3.14	1.57	1.57
Anorthite	12.51	11.68	13.07	13.07	.83	.28	1.11
Magnetite	.46	.46	1.86	-------	-------	-------	-------
Hematite	-------	-------	-------	3.68	1.76	3.20	8.96
Hypersthene	5.85	5.85	5.52	-------	-------	-------	-------
Enstatite	-------	-------	-------	3.60	1.10	.40	.20
Kaolinite	5.16	-------	5.68	2.84	35.86	32.25	27.61
Corundum	.31	-------	-------	-------	-------	-------	-------
Quartz	26.76	20.64	24.06	23.40	38.16	38.46	39.06
Modes							
K-feldspar	20	21	15	13	13	22	21
Andesine	41	37	39	39	-------	-------	-------
Quartz	28	22	26	27	24	33	29
Biotite	11	10	16	8	-------	-------	-------
Chlorite-illite	-------	1	<1	2	4	-------	-------
Hydrous Fe oxides	-------	-------	3	5	5	3	5
Clays	<1	<1	1	6	54	42	45
Sericite	-------	-------	-------	-------	-------	<1	<1
Pyrite	-------	-------	1	-------	-------	-------	-------
Accessories	<1	<1	<1	<1	<1	<1	<1

[1] A calculated correction was made for the FeO present as pyrite based on the percentage sulfur present.


B
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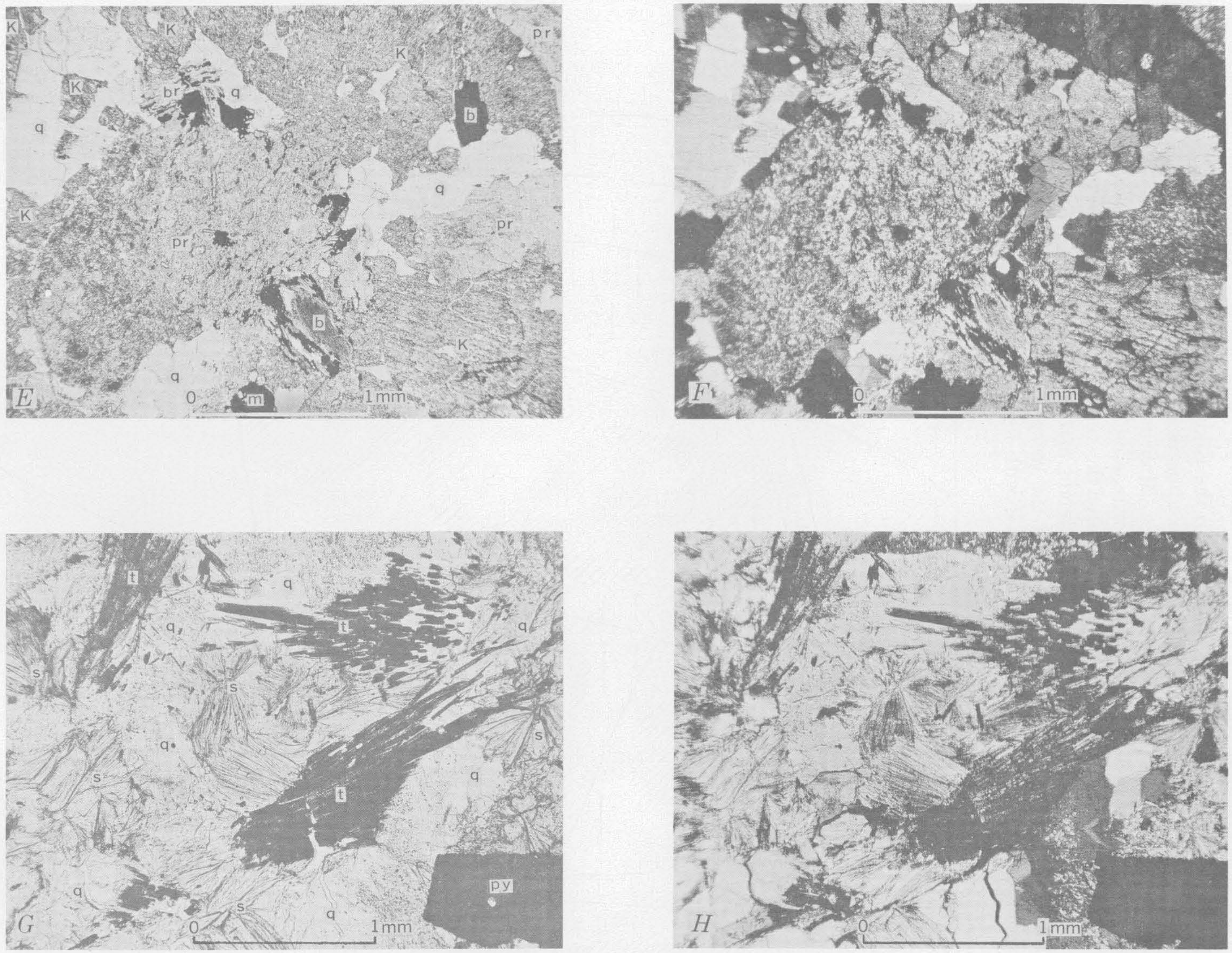

FIGURE 34.—Microscopic appearance of altered quartz monzonite adjacent to a quartz vein. *A*. Chloritic zone, early phase; note chlorite streaks (gray) in biotite lath (right center), and almost completely altered hornblende grain (top center); stained potassium feldspar appears turbid. Plane-polarized light. *B*. Same as *A*. Crossed nicols. *C*. Chloritic zone, late phase; note argillized plagioclase relict (left center), unaltered biotite in nornblende relict (center), and sericite tuffs along plagioclase cleavages (top right). Plane-polarized light. *D*. Same as *C*. p=plagioclase; pr=plagicolase relict; K=potassium feldspar; q=quartz; h=hornblende relict; b=biotite. Crossed nicols. *E*. Argillic zone; note partly altered biotite (top and bottom center) and completely argillized, partly sericitized plagioclase relicts (left and right center); unaltered stained potassium feldspar appears turbid (top and bottom right). Plane-polarized light. *F*. Same as *E*. Crossed nicols. *G*. Sericitic zone; note pyrite grain (bottom right), acicular tourmaline (center and top) and "coarse" radiate sericite (center). Plane-polarized light. *H*. Same as *G*. pr=plagioclase relict; K=potassium feldspar; q=quartz; b=biotite; br=biotite relict; m=magnetite; s=sericite; t=tourmaline; py=pyrite. Crossed nicols.

One difference between the chemical changes in the G. Washington suite and the Bunker Hill suite is the sudden increase in ferric iron in the argillic zone near the vein in the G. Washington suite. This difference (samples B255–B250, table 12) is apparently due to the abundance of hydrous iron oxide in the near-vein rock and the relative decrease in clay minerals at that point. As in the Bunker Hill suite, the specific gravity is lowest where the amount of clay is greatest.

ELKHORN MOUNTAINS VOLCANICS ADJACENT TO QUARTZ VEINS

In the Elkhorn Mountains volcanics the first alteration appears to be an increase in clay content of the rock. Mafic minerals, where present, are converted into chlorite, epidote, calcite, clays, ilmenite and leucoxene. Nearer the vein the original textures disappear among abundant mattes of fine-grained kaolinite and sericite, and the recrystallized groundmass, or matrix, is peppered with fine-grained magnetite, leucoxene, and py-

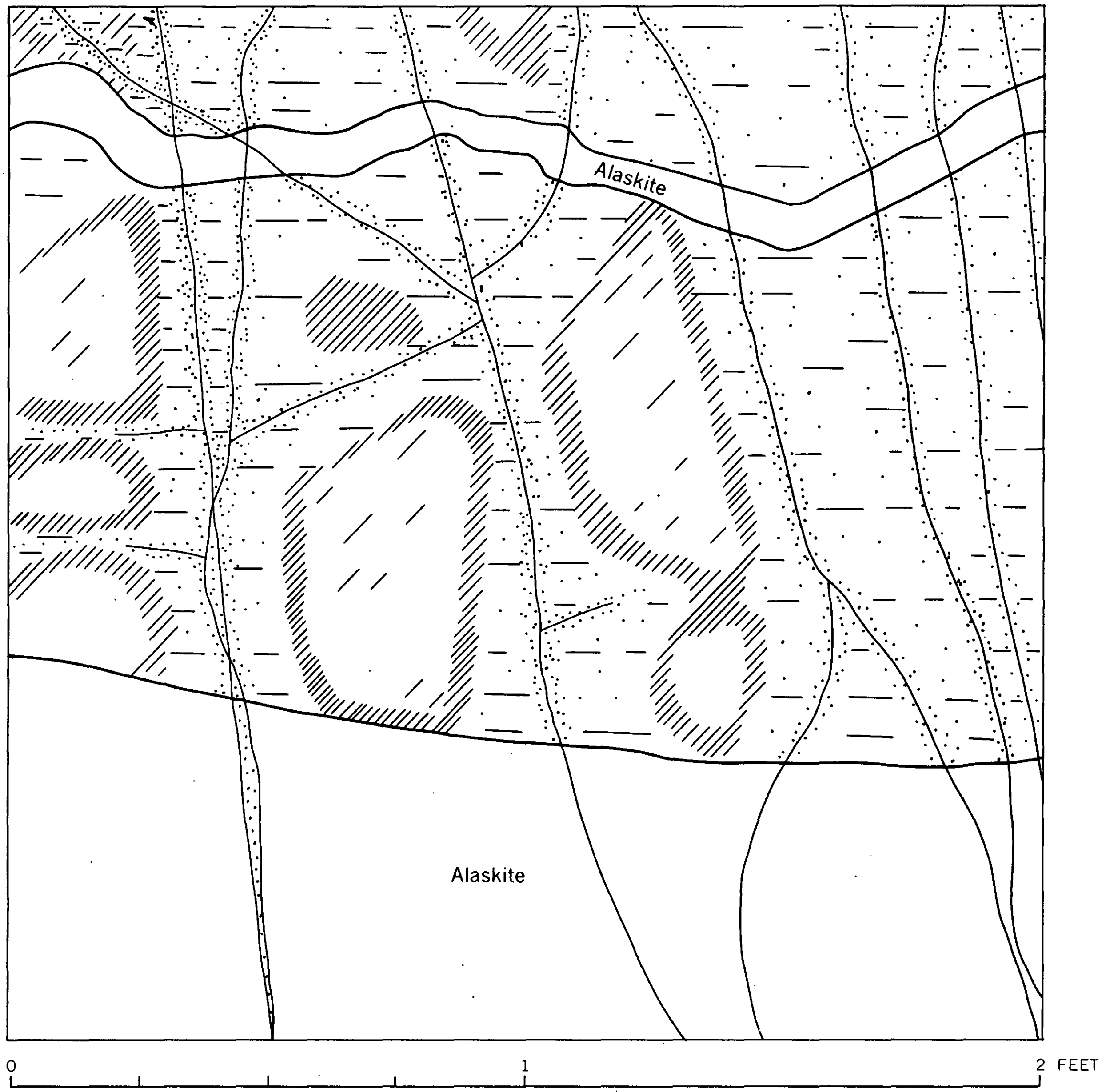

FIGURE 35.—Diagrammatic sketch of quartz veinlets cutting quartz monzonite and alaskite. Alaskite dikes are virtually unaltered. Quartz monzonite is strongly altered between quartz veinlets; chloritized quartz monzonite is surrounded by argillized (diagonally ruled), sericitized (dashed), and silicified (dotted) rock.

rite. Near-vein rock is an intimate mixture of very fine grained (about 0.001 mm) to coarser grained (about 0.1–0.5 mm) sericite and poikilitic quartz and includes sporadically distributed pyrite cubes.

COMPARISON WITH BUTTE DISTRICT

Weed (1912, p. 87–90) described chloritized and sericitized quartz monzonite in the Butte district, about 40 miles southwest of the Jefferson City quadrangle, but claimed that the broad, irregular, altered zones in the rock did not conform to the course of the veins. Kirk (1912) also described chloritization and sericitization of quartz monzonite at Butte, and he recognized lateral gradation from fresh, unaltered rock through chloritized rock to the highly sericitized, pyritized, siliceous rock adjacent to the veins. Sales and Meyer (1948, 1949, 1950), in a very detailed study of the wallrock alteration at Butte, recognized concentric zones of sericitized and argillized quartz monzonite outward from the veins and noted partial chloritization of mafic minerals at the outermost fringe of the argillic zone. Both Kirk (1912) and Sales and Meyer (1950) discuss the chemistry of the alteration in detail. Near-surface hydrothermal alteration of quartz monzonite described by Weed (1900) at Boulder Hot Springs, about 3 miles southeast of Boulder, Mont., resembles the alteration of quartz monzonite adjacent to the veins in the Jefferson City quadrangle.

Although wallrock alteration in the quadrangle is similar to that at Butte both in hand samples and under the microscope, the following differences were noted:

1. At Butte, the chloritic zone is considered a fringe on the outer edge of the alteration envelope. In the Jefferson City quadrangle, the chloritic zone is apparently much wider than the total width of all the other zones, and is considered equal in rank to the argillic and sericitic zones.
2. Sulfidation of iron released from biotite and hornblende in chloritic rock (Sales and Meyer, 1950, p. 272) is not important in the Jefferson City quadrangle. Instead, most of the released iron precipitated as magnetite and (or) ilmenite in the cleavages of biotite or as specks and irregular masses in and around the margins of biotite and at the sites of former hornblende grains.
3. The allophane-hisingerite type amorphous clay mineral (Sales and Meyer, 1948, p. 17) was not recognized in this area. Its deep azure blue color was noted at Butte shortly after the smoke of blasting cleared away but no such opportunity was available here. The only bluish coloration noted was in partly argillized quartz monzonite at the G. Washington mine, but it was due to very fine grained chalcanthite coatings on innumerable fractures in the rock.
4. Fringes of regenerated biotite after chlorite around primary biotite grains in the kaolinite subzone (Sales and Meyer, 1948, p. 19) were not observed in any of the alteration suites in comparable quartz monzonite in this area even though they were specifically looked for. In contrast to relations at Butte, chloritization was not arrested when the argillization of plagioclase became intense. Instead, chloritization of biotite went to completion in some instances. The process was apparently overtaken by muscovite, illite(?), and kaolinite formation in the argillic zone because biotite relics often consist of muscovite laths with associated magnetite or ilmenite, and minor amounts of illite(?) and kaolinite. Apparently the chloritization process in this area was not reversed. Nowhere was fresh biotite available for attack at the sericite front.
5. Not reported in the chloritic and argillic zones at Butte were the formation of ilmenite from hornblende and subsequent transformation of ilmenite to considerable amounts of leucoxene (as much as 6 percent of the rock); and the formation from biotite of a colorless, crinkly, micaceous mineral that looks like bleached biotite and is tentatively identified as illite. Illite(?) after biotite is fairly common in the alteration suite from the G. Washington mine, one of the few suites in which this material is the majority alteration product of biotite.
6. Tourmaline is not present at Butte but is present in altered rock near many of the quartz veins in the Wickes district.

AGE RELATIONS

Quartz veins and chalcedony veins are both younger than any rocks of the batholith. The quartz veins, except for those in the northeastern part of the quadrangle, are clearly older than the quartz latite of Oligocene age, and we believe those in the northeastern part are too. The age relations between the chalcedony veins and the quartz latite and between the quartz veins and the chalcedony veins are not as certain. Some chalcedony is probably younger than the quartz veins. Chalcedony deposition appears to have extended throughout a long period.

Before the Tertiary episode of volcanism the quartz veins were oxidized and eroded, and during the volcanism they were intruded by dikes and locally covered by tuff. The quartz veins at the Comet mine (100) are cut by quartz latite dikes (pl. 13), and at several other mines, such as the Bismark (103) and Mount Washington (46), the dikes have intruded and split the veins. On the western side of Alta Mountain in the south-central part of sec. 9, T. 7 N., R. 4 W., oxidized outcrops of quartz veins extend under the quartz latite tuff, and at Rimini oxidized quartz veins on the western side of Red Mountain extend eastward to the rhyolite of Tertiary age, but neither veins nor alteration have been found in the tuff or rhyolite.

Knopf (1913, p. 54) considered the quartz and quartz-chalcedony veins in the northeastern part of the quadrangle to be younger than the quartz latite and therefore younger than the rest of the quartz veins in the quadrangle. This was based on relations at the King Solomon mine (39), where Knopf noted (1913, pp. 104–105) that a quartz latite dike, parallel to the vein, had a "wavy" wall and that "the lode pursues a straighter course than the dike and touches the footwall of the dike at the crests of the waves only. At such points the dike is generally much sheared and altered." He interpreted these relations to mean that the vein was younger than the dike because the dike appeared altered near the vein. The mine is now inaccessible and the relations described by Knopf cannot be seen, but if the dike is older than the vein, the dike probably should be altered in the same manner as the batholithic wall rocks of the vein and this does not seem to be so. The batholithic rocks on the dump are altered to sericite; the most "altered" looking quartz latite on the dump contains much clay but no sericite. Because of the lack of sericite in the quartz latite, we believe that the dike probably was not hydrothermally altered by the solutions that deposited the vein but that the clay resulted from weathering. The dike is probably post-vein rather than prevein in age.

Relations similar to those described by Knopf also exist at places where the quartz latite dikes are clearly later than the veins. The dike at the Bismark mine (fig. 47) is a good example. There a quartz latite dike has cut and split the vein and broken it into segments. The edges of the dike are sheared and gougy or have been converted to clay in place (presumably by weathering), but the dike rock has not been altered to sericite as have the batholithic wall rocks of the vein even though the dike is in contact with sericitized batholithic rock. A similar situation is noted at the Monte Christo adits (64).

The age relations between the quartz veins and the chalcedony veins are not known because veins of one type have not been found cutting veins of the other. The mineral assemblages of the quartz veins and the altered zones adjacent to them suggest a higher temperature of formation than does the mineral assemblage in the chalcedony vein zones, which suggests that the chalcedony veins may be younger. Many quartz veins contain tiny stringers of chalcedony or iron-stained microcrystalline quartz similar to that in outcrops of chalcedony veins. These stringers are the latest material deposited in the quartz veins, but they may not be of the same age as the chalcedony veins; some might be supergene and as young as Recent.

Nearly all chalcedony veins are older than the Tertiary period of volcanism, but a little chalcedony may be younger. In the southwest corner of sec. 1, T. 6 N., R. 5 W., chalcedony veins are cut off by a large quartz latite intrusive body. The quartz latite appears fresh and contains no chalcedony. The same thing is true in many places where chalcedony veins and quartz latite dikes are in contact or approach each other. In a few places, however, quartz latite dikes are silicified and contain chalcedony. An example is a quartz latite dike along the south-central edge of sec. 35, T. 8 N., R. 4 W., in which chalcedony was deposited in veinlets and irregular masses. Along the north side of Westover Gulch, in sec. 29, T. 8 N., R. 3 W., a chalcedony vein 5 inches wide in a wider silicified zone in batholithic rocks narrows to less than 1 inch where it crosses a quartz latite dike. The dike is bleached and apparently altered for 6 to 12 feet adjacent to the vein.

Some mineralization in the quadrangle is younger than the quartz latite. At the Montana Tunnels (52), a conglomerate (or possibly a breccia pipe) contains mineralized cobbles of quartz latite in a tuffaceous matrix. This deposit is therefore probably younger than the oldest quartz latite. It is different from any of the vein deposits (see p. 51); and nothing similar to it is known in the quadrangle.

MINERALIZED BRECCIA PIPE

An altered and mineralized breccia pipe crops out as a pinnacle on the northern side of the Boulder River canyon in sec. 15, T. 6 N., R. 5 W., about 1 mile east of the mouth of Cataract Creek. The pipe has been explored by workings of the Obelisk mine (pl. 4), a name derived from the pinnacle outcrop; these workings include 1 shaft collared at the outcrop, 2 short adits, 1 main tunnel level about 200 feet below the outcrop, and 1 winze reported to extend 190 feet below the tunnel level (see also page 97). The pipe is roughly lenticular in plan, elongate about 300 feet eastward. From the outcrop to the main tunnel level, the eastern end of the pipe plunges 70° S. 15° W.

The breccia is made up almost entirely of coarse, angular to well-rounded fragments of quartz monzonite in a matrix of sand; it also contains some alaskite fragments and a very small amount of brecciated carbonate vein material. The most abundant fragments are 6 to 10 inches across, but fragments as large as 3 feet are common, especially near the edge of the pipe. The smallest fragments that are abundant are 2 to 3 inches across and are well rounded. On the lower tunnel level, small fragments (some only half an inch in diameter) are most common in a mineralized conduit. In most places the breccia becomes coarser and less rounded toward the edge of the pipe, so that the edge is not distinct; near the eastern end of the pipe, however, the edge is well defined.

Throughout most of the pipe a well-sorted sand fills the spaces between the breccia fragments. The sand is composed almost entirely of poorly cemented angular fragments of quartz and feldspar, commonly medium sized but ranging from silt to coarse sand. Calcite is the most common cementing material. There is no gradation between the sand matrix and the breccia fragments. The largest breccia fragments are surrounded by the same sand matrix as the smallest fragments.

Several thin tabular sand bodies a few to several inches wide cut the breccia and the surrounding batholithic rocks. These bodies are probably not thin fault breccias, because they contain no gouge (which accompanies even the smallest faults in the batholith). The sand in the bodies seems to be identical with the sand matrix of the breccia. All the tabular sand bodies observed are in the pipe or close to it, and those outside the limits of the pipe either connect with it along strike or appear to be connected downdip. These bodies seem to be small dikes of sand injected into the breccia and the surrounding rocks. Some boulders in the breccia outcrop are mostly sand, and in parts of a few of them the sand appears sorted and bedded. The bedding planes are slightly curved and fade out within a few inches into unbedded sand. The bedding consists of thin layers composed largely either of small zircon crystals or of quartz and feldspar.

Mineralization in the breccia pipe has occurred mainly along a small conduit that plunges parallel to the eastern end of the pipe and apparently swells to form ore bodies 30 or 40 feet across. The conduit extends from the collar of the shaft downward through a large stope on the main tunnel level and beyond for at least 190 feet. The stope is about 15 by 40 feet and tapers upward to a height of about 30 feet; old maps of the winze show three more stopes of comparable size at depths of 50, 65, and 140 feet. Within the mineralized conduit on the main tunnel level is a wedge-shaped body in which the matrix is composed entirely of sulfide minerals, largely sphalerite with abundant galena and some fine-grained quartz. This body narrows and merges with a thin vein along the southern wall of the pipe.

In a general way, alteration of the breccia fragments decreases in intensity outward from the mineralized conduit. Within the conduit where sulfides form the matrix, the rock fragments are strongly altered to clay and some sericite. The breccia surrounding the conduit contains a great deal of fine-grained quartz in place of the sand matrix. Still farther outward, the matrix is both fine-grained quartz and sand, the quartz appearing to have replaced the sand, and beyond this the matrix is entirely sand. From the mineralized conduit to the edge of the breccia pipe, the plagioclase in most of the smaller fragments has been altered to clay. Most of the potassium feldspar and the cores of the larger blocks are unaltered.

The ore minerals in order of decreasing abundance are sphalerite, galena, pyrite, and chalcopyrite; the gangue is very fine grained quartz and, in places, rhodochrosite and siderite. The sphalerite is a fine- to coarse-grained blackjack variety. The galena is fine to medium grained with distorted cleavage planes, and it contains an unidentified silver mineral. Chalcopyrite is sparse in the ore; it occurs as small grains with sphalerite, as exsolution bodies in sphalerite, and as a replacement of sphalerite (J. W. Allan, written communication). Pyrite is sparse within the mineralized conduit but is more abundant in narrow veins, both in the drift east of the pipe and along the southern wall, where it is associated with quartz. The quartz within the pipe is typically a fine-grained variety that is deposited on the sulfide minerals and lines vugs in the mineralized conduit. The quartz in the veins with pyrite is a little coarser. A few veinlets in and near the breccia contain only siderite. Rhodochrosite, although rare, is found in the quartz-pyrite veins in the drift east of the pipe and in a few small vugs in the breccia.

MINERALIZED CONGLOMERATE OR BRECCIA PIPE

A partly mineralized tuffaceous conglomerate or breccia pipe was mined in about 1900 at the Montana Tunnels (52) in sec. 8, T. 7 N., R. 4 W. This deposit, near the western edge of a large area of Lowland Creek volcanics, is unique in the quadrangle. The country rock near the two caved tunnels is composed mostly of well-rounded pebbles, cobbles, and boulders as much as 12 inches in diameter in a white tuffaceous matrix that contains small quartz crystals. The conglomerate is composed largely of Elkhorn Mountains volcanics and batholithic rocks but includes a few pebbles of quartz latite. Where exposed, the conglomeratic rock is not bedded and contains no silt or sand. It is in contact with a fine-grained quartz latite tuff of the

Lowland Creek volcanics that resembles the tuffaceous matrix of the conglomerate, and the attitude of the contact is N. 30° E., 80° NW. Some fragments of the Elkhorn Mountains volcanics on the dump of the lower tunnel are not rounded, indicating that the tunnel was driven beyond the edge of the conglomeratic rock into the underlying Elkhorn Mountains volcanics.

The rock is poorly exposed and its origin is not known. Its position near the edge of the area of tuff and the roundness of its cobbles suggest that it is a conglomerate near the base of the tuff, as Knopf (1913, p. 116) considered it; however, because it is in an area of volcanic activity and has a tuffaceous matrix, it could be a breccia pipe.

The rock from the tunnels and in a pit above them is mineralized. The rock in the pit is bleached and altered and contains small grains of disseminated pyrite, mostly in the altered cobbles, and both coarsely crystalline and microcrystalline quartz in the matrix. Sphalerite and a little galena and ruby silver (?) were found on the dumps of the tunnels. Oxidation probably extends only a short distance below the surface.

Soil in the vicinity of the Montana Tunnels has a very high metal content over an area at least 2,400 feet by 1,200 feet, probably because of the underlying mineralized conglomerate or breccia pipe. The extent of the soil anomaly suggests that the mineralized area is larger than the area of Tertiary quartz latite shown on plate 1. The mineralized rock probably extends southward under the thin landslide debris in the south-central part of sec. 8, T. 7 N., R. 4 W. The deposit seems to be along the westward extension of the Alta vein in the Wickes district.

PLACER DEPOSITS

Placer gold deposits in the quadrangle are along Lump Gulch and Prickly Pear, Spring, Clancy, Buffalo, Banner, Cataract, Overland, Big Limber, High Ore, and Homestake Creeks. Only those deposits in Clancy and Prickly Pear Creeks have been extensively worked. The other placers are small or the gravels contain many large boulders, which hinder placer mining. Beyond the borders of the quadrangle, placer deposits have been found along Tenmile Creek and the Boulder River.

According to Lyden (1948, p. 42–44), more than 49,020 ounces of gold came from the gravels along Prickly Pear Creek, and 8,594 ounces came from the Clancy Creek placers. The Prickly Pear gravels averaged from 13 to 25 cents per cubic yard, and the Clancy Creek gravels averaged about 13 cents per cubic yard.

In 1938 a Yuba connected-bucket floating dredge was installed on Prickly Pear Creek about 3¾ miles below Jefferson City and worked upstream to the confluence of Beavertown Creek. From this strip of placer ground, about 4 miles long and 1,000 feet wide, the dredge reportedly recovered gold worth about $1.5 million. The rest of the placer mining on Prickly Pear Creek and all of that on Clancy Creek was done by different types of dryland dredges.

BOG DEPOSITS

MANGANESE

A postglacial bog manganese deposit along the south side of Kady Gulch in sec. 1, T. 7 N., R. 5 W., is about 100 feet long, 80 feet wide, and 2 to 3 feet thick (Pardee and Schrader, 1933, p. 234). Pits and trenches (60) have been dug to explore the deposit, and a few carloads of ore were shipped in 1942. The bog probably contains a few hundred tons of high-grade manganese ore. A smaller bog is a short distance to the north in a small draw along the side of the Kady Gulch.

NATIVE COPPER

Copper leached from chalcopyrite-bearing quartz veins on the ridge west of Beavertown Creek has been deposited in a bog in the Copper Gulch area (71) as native copper. The deposit is small and low grade. According to Forrester (1942, p. 126–135), the metal was precipitated by iron oxide; but conditions causing precipitation have changed, and little if any copper is now being deposited.

SUGGESTIONS FOR EXPLORATION

The mines in the Jefferson City quadrangle have no known reserves, and thus the mineral potential of the quadrangle is difficult to assess. The veins that have been most productive—the quartz veins—have very inconspicuous outcrops or do not crop out at all, and parts of the quadrangle are heavily timbered or covered with moderately thick overburden; thus there is no reason to assume that all the deposits of economic value have been discovered. All but two of at least 40 deposits that have yielded more than 1,000 tons of ore apiece were found at the surface, 31 of them in places where the soil is very thin. This suggests that thorough prospecting along projections of veins or altered zones in areas of thick overburden might discover concealed ore bodies. Furthermore, several of the known deposits in the quadrangle do not appear to have been throughly developed and consequently might be favorable ground for a carefully planned prospecting program.

One of the parts of the quadrangle most promising for concealed deposits is the area west of Alta Mountain, where quartz latite tuff of the Lowland Creek volcanics of Oligocene age and gravels of Quaternary age appear to overlie parts of at least three major east-trending shear zones—the Alta zone, the Minah zone. and the Bluebird–Mount Washington zone (67, 49, and 43–46 on pl. 1). These structures may even be continuous, under a soil cover, with other known structures and so continue as far west as the Occidental Plateau. The Alta structure appears to extend under the tuff to the area of the General Harris mine (50) and farther westward to the Bonanza-Dewey tunnels (54, 55) shear zone and the Blackbird (53) shear zone. The Minah structure may extend eastward under the tuff to a small area of prospects and altered rock in the south-central part of sec. 9, T. 7 N., 9. 4 W., although no evidence for such an extension was found in the long No. 4 level crosscut of the Minah mine (pl. 5). Westward, the structure probably extends to a group of adits near the bed of Clancy Creek, passing through the 1,200-foot Dow crosscut (57), where it may be represented by a vein 2 feet wide near the end of the crosscut or by another nearer the portal. The long Bluebird–Mount Washington shear zone may extend eastward under the tuffs and gravels to intersect northeast-trending structures in the vicinity of the David Copperfield adit (69). A fourth east-trending structure, represented by a fault along Wood Chute Creek near the Salvail mine (45), may extend eastward under the gravels into the area of the Daily mine (70), where it would intersect northeast-trending structures similar to those found in the workings of the Daily mine.

If these major shear zones extend under the cover of tuff and gravel, they may contain ore bodies, but nothing on the surface indicates either where these structures may be or where ore might be along them. The gravel is probably a few tens of feet thick. The thickness of the tuff is not known, but in most places along its margin it is probably thin. Maximum relief in the tuff west of Alta Mountain is about 600 feet, and east-west profiles across the area near the Minah and Alta mines indicate only about 200 or 300 feet of tuff under the deeper valleys.

To determine whether indications of ore could be found by geochemical methods along extensions of the major structures under the tuff, a soil sampling program was carried out in 1956 by the Geological Survey. Samples were taken at 200-foot intervals along north-south lines laid out about 500 feet apart, and they were analyzed spectrographically (pl. 5). According to Mr. Uteana Oda, who analyzed all of the samples, silver, lead, copper, manganese, and zinc were the only indicator elements in the samples. An area of high metal content was found in the soil around the Montana Tunnels (52), north of the Minah vein. This area extends at least 2,400 feet north and south and 1,200 feet east and west, but the total extent was not determined; samples from it contained, in parts per million, as much as 5,000 parts of manganese, 3,500 parts of lead, 200 parts of copper, and 35 parts of silver. So high a metal content probably indicates that a moderately large area is underlain by mineralized rock and could indicate a deposit suitable for open-pit mining methods; however, additional soil sampling, on a more closely spaced grid, and more detailed geologic mapping are required before the deposit can be evaluated.

Similar methods of exploration might be useful elsewhere in the quadrangle. All but one of the ore bodies that have been mined along the extensive Comet–Gray Eagle shear zone were found by looking for outcrops. The Van Armin (104), Bismark (103), Australian (102), Comet (100), and Gray Eagle (99) ore bodies crop out on gently sloping, untimbered hillsides or on ridge tops where bedrock is very close to the surface, and they were easily found in the early days of mining. The Morning Glory veins (98), which crop out on heavily timbered slopes covered with thick mantle, were not found until more than 40 years later. Additional ore bodies that may underlie covered areas along the shear zone or that may apex below the surface might be found by systematic soil sampling along the entire length of the main shear zone and the Bismark–Van Armin zone which branches from it. Whether or not geochemical methods would indicate blind ore bodies could be determined by sampling the soil above the east ore body at the Gray Eagle mine (see p. 86), which was discovered underground. The top of this ore body is about 300 feet below the surface.

The Lee Mountain–Valley Forge shear zone in the Rimini district apparently has not been explored between the two major mines (1 and 3) except by short, near-surface adits. Soil sampling along this zone might indicate other mineralized areas.

The Rimini district offers several other possibilities for future exploration. West of the rhyolite on Red Mountain, the Red Mountain fault cuts Butte quartz monzonite and may have offset some of the productive veins, but apparently little attempt has been made to discover the horizontal component of movement on this fault. According to Paul A. Gow of Butte (written communication), the Eureka (7) vein may be the offset segment of the productive Free Speech (9) vein, indicating a possible horizontal displacement of about 625 feet to the right along the fault. On the other hand, the offset of the Lee Mountain–Valley Forge zone along a probable extension of the fault is about 600 feet to the left. If the horizontal displacement is about 600 feet to the left, the O. H. Bassett (10) and Mammoth (6) veins probably are offset segments of the same vein, and the Free Speech vein has not been found east of the fault.

The Red Mountain Tunnel (8), a crosscut 3,300 feet long, was driven southeastward into Red Mountain to develop the veins there at depth. It cut the Red Mountain fault and 40 or more veins, but, according to the best information available, little or no exploration was done on any of the veins except three—the Free Speech, Eureka, and Alta (pl. 6). Some of the productive veins known on the surface were not found in the crosscut, or at least were not recognized and explored; they are projected to the crosscut level on plate 6. Whether two of these veins—the Mammoth and O. H. Bassett veins—exist at depth could be determined by exploration from the Red Mountain Tunnel level. A crosscut in the footwall of the fault northeastward about 300 feet from the drift on the Free Speech vein would reach the Mammoth vein if it extends 1,000 feet below its outcrop and would also explore a block of ground that might contain other veins. The O. H. Bassett vein on the surface is nearly parallel to and about 350 feet south of the Free Speech vein. It was not found in the Red Mountain Tunnel, but should end against the Red Mountain fault at a point about 250 feet south of the tunnel crosscut. A crosscut to the O. H. Bassett vein, driven along the western wall of the fault, would explore the unknown block between the Red Mountain Tunnel and the O. H. Bassett vein.

Many of the mines in the Jefferson City quadrangle are inaccessible and their potential cannot be judged, but accessible workings of a few mines indicate that some deposits may not have been thoroughly explored. The following possibilities for additional ore in or near mines were noted during mapping of the quadrangle.

A drift about 500 feet east-southeast of the portal of the lower or No. 1 adit of the Bunker Hill mine (13) in th Rimini district exposes a north-trending vertical fault of unknown displacement (fig. 36). The possibility of offset of the vein exposed in the No. 2 adit 400 feet above the No. 1, apparently has not been explored. This vein was productive above and below the No. 2 adit but has not been explored at depth. It could probably be found by extending the No. 1 adit eastward across the fault and crosscutting from the adit to the north and south. The Teal Lake (14) vein, which is only about 100 feet south of the Bunker Hill vein, could easily be tested by short holes or crosscuts driven from the Bunker Hill No. 2 adit. The eastward extension of the Daniel Stanton (12) vein is not known from existing maps and might be explored in the same way from the Bunker Hill No. 1 adit.

The Gray Eagle mine (99), one of the largest in the quadrangle, was closed because the known ore bodies were mined out; however, the possibility of another ore body below the 700 level exists. The east ore body in the North vein was found to end abruptly about 20 feet below the 600 level, and in its place barren carbonate minerals extend down through the 700 level. The carbonate minerals in these veins are late, and it is entirely possible that the ore body extends below this barren carbonate-rich part of the vein—a possibility that apparently was not explored.

The structure of the vein zone at the Baltimore mine (89) is complicated by horsetailing, by several faults, and by a post-ore dike. These factors were overlooked by operators of the mine, who consequently drove many short drifts and crosscuts on the upper levels that ended in barren rock. Ore bodies apparently were not explored to their limits. Several possibilities for additional ore in the Baltimore mine are discussed in the mine descriptions (p. 92), where the complex structure of the vein zone is described in detail.

Most of the uranium deposits that have been found are too small to be mined economically, and the chances of finding larger deposits appear small. It should be noted, however, that some of the uraniferous veins are not radioactive on the surface and have been found to contain uranium only because radioactive material was detected on the mine dump.

Only a small amount of known gold-placer ground remains unworked in the quadrangle. Short stretches of Prickly Pear Creek above its confluence with Beavertown Creek probably could be worked by draglines. About 3½ miles of unworked gravels remain along Clancy Creek, but the gold-bearing gravel is probably covered by at least 35 feet of overburden.

MINING DISTRICTS AND MINES

RIMINI DISTRICT

The Rimini district (sometimes referred to as the Vaughn district) includes the northwestern part of the quadrangle; as used in this report, it extends south to the upper Cataract Creek drainage area and east to Lava Mountain and Frohner Meadows. Part of the district is northwest of the quadrangle, but the major mines are in the quadrangle area. A good graded gravel road extends from the town of Rimini for 7 miles northward to U.S. Highway 10, about 10 miles west of Helena.

Within the quadrangle, the bedrock of the district consists of medium- to coarse-grained Butte quartz monzonite and rhyolite, which form Red Mountain. Alaskite is sparse. Much of the area is covered by glacial deposits, landslides, or alluvium. The major structural features of the district are the Lee Mountain-Valley Forge shear zone, which trends northeastward across the northwest corner of the quadrangle, and the Red Mountain fault, which trends northward on the western side of Red Mountain and offsets the veins. Minor structural features include small, north-trending, steeply dipping faults, which cut many of the veins but offset them by only a few feet. There are a few chalcedony veins in the vicinity of Chessman Reservoir, but all the mines in the district are along quartz veins.

More than 100 quartz veins are known in the district, and most of those that are within the quadrangle are in two areas. The northern area includes all the veins on the western side of Red Mountain and extends northward to the Lee Mountain-Valley Forge shear zone. Almost all the veins within this area, except for some along the Lee Mountain-Valley Forge zone, strike nearly east and dip between 75° S. and 90°. The veins in the southern area south of Red Mountain strike between N. 60° E. and N. 80° E. Most of them probably dip steeply, but a few dip between 50° and 60°, either north or south. Tourmaline is abundant in many of the veins in the northern area but is a minor constituent of most veins in the southern area.

Most of the primary ore from the Rimini district contains 0.25 to 0.5 ounce of gold and 20 to 30 ounces of silver per ton, several percent each of lead and zinc, and only a little copper. A large part of the ore contains several percent arsenic in the form of arsenopyrite; such ore is penalized by the East Helena smelter and requires milling.

In 1953 several mine dumps in the district were found to be radioactive, and hand specimens containing as much as 0.65 percent uranium were collected. The radioactive material is in quartz veins rather than chalcedony veins. The deposits are too small to be mined economically. Localities where radioactivity was found include the Daniel Stanton mine (12) and two groups of small mine workings (pl. 1, nos. 5 and 18). The entire dumps of the Horsefly adit (17) and the Ida May mine (21) are slightly radioactive.

LEE MOUNTAIN-VALLEY FORGE SHEAR ZONE

The Lee Mountain-Valley Forge shear zone trends N. 50°–60° E. and dips steeply. It consists of faults, veins, and altered rock across a width of a few hundred feet, and it extends about 5 miles southwestward from the northwest corner of sec. 34, T. 9 N., R. 5 W. Beyond the west edge of the quadrangle, the shear zone is covered by rhyolite and glacial deposits, but it is exposed beyond the covered area in the valley of Minnehaha Creek (Ruppel, 1963). Two of the larger mines in the Rimini district, the Lee Mountain (1) and Valley Forge (3) mines, are along this zone. Between these mines the zone is marked by many prospect pits and short adits driven into altered rock.

Veins along the zone contain either quartz and tourmaline or quartz and sulfide minerals. According to Billingsley and Grimes (1918, p. 305) and Billingsley (written communication), the veins of quartz and tourmaline strike nearly east and in places are cut at a low angle by northeast-trending veins containing quartz and sulfide minerals.

LEE MOUNTAIN MINE

The Lee Mountain mine (1) is in sec. 33, T. 9 N., R. 5 W. It has been described in some detail by Knopf (1913, p. 83–84) and by Pardee and Schrader (1933, p. 255–257). The deposit was discovered in 1864 and was most actively worked before 1900. Prior to 1913, production amounted to $1.5 million, of which $750,000 is authenticated (Knopf, 1913, p. 83). Records of A. T. Cooper, Helena, Mont., indicate that from 1902 to 1904, 18,642 tons of ore containing 0.25 to 0.50 ounce of gold and 15 to 30 ounces of silver per ton and 5 to 11 percent lead were produced, and that metals produced from 1934 to 1938 amounted to 727,916 pounds of zinc, 643,464 pounds of lead, 75,657 ounces of silver, and 598 ounces of gold.

The mine consists of seven main levels, all caved near the portals, and a flooded shaft that extends below No. 7 level. On the No. 7 level (pl. 7) the vein is made up of many parallel or subparallel stringers, veins, and lenses of either quartz and tourmaline or quartz and sulfide minerals, which are as much as 10 feet wide and dip steeply south in a zone about 60 feet wide. Most of the veins and lenses strike northeast, but some veins of quartz and tourmaline strike nearly east. The intervening batholithic rock is intensely altered. Both the altered wallrock and the vein are cut by many northeast-, east-, and northwest-trending faults.

VALLEY FORGE MINE

The Valley Forge mine (3) is in sec. 33, T. 9 N., R. 5 W. The mine was probably first operated in the 1870's or 1880's and was operated again from 1907 to about 1920. Production before 1913 amounted to $200,000 (Knopf, 1913, p. 82). Probably several thousand tons of ore were produced between 1914 and 1919. In 1946, 3,000 tons of dump material was milled, and in 1947, 556 tons of lead-zinc concentrates was produced from dumps (U.S. Bur. Mines, 1946, 1947).

The mine workings include two caved shafts near the top of the hill, two adits west of the shafts, a crosscut 2,000 feet long from Rimini, a raise from the crosscut connecting it to the upper workings, and levels at approximately 100-foot intervals in the raise. An aerial tram extended from the adit at an elevation of about 5,500 feet to the railroad at Rimini.

A banded vein of quartz, tourmaline, and some sulfide minerals about 4 feet wide is exposed in the middle adit (alt. 5,800 ft) for about 500 feet. The ore is in two bodies, called the east and west bodies, that are separate from the quartz-tourmaline part of the vein; they may be adjacent and parallel to it (Knopf, 1913, p. 83) or they may cut across it at a low angle (Billingsley and Grimes, 1918, p. 305). The east body, about 300 feet long near the shafts, was worked to a depth of 200 feet. The west body, east of the upper adit, was 350 feet long and extended below the 600 level (the actual depth is not known but is probably about 200 to 300 feet below the middle adit). Below these ore bodies the vein is low grade, and no additional ore was found on the long crosscut level.

Two shafts and two adits (4) are about 1,000 feet northeast of the Valley Forge shafts along the northeastern end of the Lee Mountain–Valley Forge zone. In these shafts and adits, galena, pyrite, and arsenopyrite occur in a gangue of quartz and tourmaline. Some of the ore is brecciated and cemented by pyrite and arsenopyrite.

LITTLE LILLY GROUP

The Little Lilly group (2) is in sec. 33, T. 9 N., R. 5 W., on the east side of Tenmile Creek. The greatest period of production was from 1937 to 1940, when a few thousand tons of ore was shipped. The mine workings consist of a 167-foot shaft, an inclined winze, 2 adit levels, and 1,500 feet of drifts, all of which are inaccessible. According to Mr. A. T. Cooper (oral communication) the vein trends eastward; it probably branches from the Lee Mountain-Valley Forge zone.

MINES ON THE WESTERN SLOPE OF RED MOUNTAIN

RED MOUNTAIN TUNNEL

A cluster of quartz veins on the western slope of Red Mountain have been extensively mined and explored. In 1927 the Montana Lead Co. was organized to drive a long crosscut, called the Red Mountain Tunnel (8), to many of these veins. Starting at Tenmile Creek at an altitude of 5,400 feet, the crosscut followed a course of S. 37° E. for 3,330 feet and S. 10° W. for an additional 170 feet (pl. 6). The large Red Mountain fault was cut and 40 or more veins were found, the strongest of which are the Free Speech, Alta, and Eureka veins. The Eureka vein had been previously mined from the surface in the Eureka mine. The Free Speech vein was subsequently developed by a raise and adits, and the Alta vein was explored underground. In 1934 the company was a major producer of lead in Montana; most of the ore was from the Free Speech mine. By 1937 the properties had been turned over to lessees and only a few hundred tons of ore was produced (U.S. Bur. Mines, 1934–37), and by 1940 the company was dissolved (Trauerman and Waldron, 1940, p. 54). In recent years the crosscut has become partly caved and flooded in places, so as to be accessible only with difficulty. Information about the veins is largely from company maps and reports.

Alta vein.—The Alta vein in the crosscut strikes nearly east. It was explored along a drift for 280 feet east and 65 feet west from the crosscut, and a 65-foot raise was put up on the vein east of the crosscut. The vein is narrow but contains several percent of both lead and zinc and a few ounces of silver to the ton. It has not been mined from the surface.

FREE SPEECH MINE

The Red Mountain Tunnel cut the Free Speech vein 2,260 feet from the portal, and a raise was put up 360 feet from the crosscut level through an ore body that did not extend to the surface. Two adits (9) were subsequently driven to find the upward extension of the ore (pl. 8). According to Mr. A. T. Cooper, manager of the South Dakota Mining Associates, which succeeded the Montana Lead Co., almost all the company's production came from the Free Speech vein, presumably from this one ore body.

In the Red Mountain Tunnel the Free Speech vein strikes N. 83° E. and dips 77° S. It is 6 feet wide, but the ore is low grade. In the No. 1 adit west of the ore body, the mineralized part of the vein zone pinches and swells along strike and contains several strong quartz veins that are subparallel. The vein material ranges from a thin stringer to 6 feet in width and is chiefly quartz but also contains some galena and pyrite. In the No. 2 adit, the mineralized veins also pinch and swell along strike; but generally they are less continuous and not as wide as in the No. 1 adit, even though the No. 2 adit is less than 100 feet above the ore body.

The ore is mostly galena containing gold and silver, associated with pyrite and arsenopyrite in a gangue of coarse milky quartz, altered wallrock, and some fine-grained quartz and chalcedony. Arsenopyrite is very abundant on the lower adit dump but less abundant in much of the shaft dump. Below the mine workings in the Red Mountain Tunnel, the vein is mostly quartz and pyrite with a small amount of galena and sphalerite. The vein apparently contains a pod of arsenopyrite that does not extend far below the drift near the bottom of the shaft and certainly does not reach the level of the Red Mountain Tunnel.

EUREKA MINE

The Eureka mine (7) is in sec. 4, T. 8 N., R. 5 W. The vein was discovered in 1865 and was mined, chiefly between 1898 and 1900, by two adits 140 feet apart vertically, a shaft 400 feet deep, and a drift 462 feet long that runs eastward from the bottom of the shaft. The shaft is in good condition down to the water table at a depth of about 100 feet. The lower adit is 890 feet long (Pardee and Schrader, 1933, p. 251; Montana Inspector of Mines, 1900, p. 32); an ore body 465 feet long and 2½ feet wide was stoped above it, according to Pardee and Schrader. An aerial tram formerly connected the mine to the railroad at Rimini.

The Eureka vein strikes east and dips steeply to the south. It ranges in width from 4 to 10 feet and is 5 feet wide in the Red Mountain Tunnel (pl. 6), below the Eureka mine workings. To the west the vein is cut off by the Red Mountain fault.

MAMMOTH MINE

The Mammoth vein is a strong quartz vein that strikes about N. 85° W. and dips 83° to 87° S. It crops out at the surface and has been mined (6), but it was not found in the Red Mountain Tunnel (pl. 6). Material on the adit dump at the western end of the vein zone is mostly altered quartz monzonite containing stringers of vein material. A few hundred feet to the east in several large pits the zone is composed of 6 feet of gray to milky quartz, bordered on the footwall by a zone 1 to 2 feet thick of intensely altered wallrock, which is cut by many quartz stringers half an inch wide. Beyond this zone the footwall is intensely altered to sericite. The hanging wall of the quartz vein is bordered by a zone 1 foot thick of intensely iron-stained and probably sericitized rock, which is in turn bordered by wallrock that appears to be altered largely to clays. The zone of many quartz stringers and the wide sericitized zone in the footwall of the quartz vein do not seem to be present in the hanging wall. A few hundred feet to the east of the pits the vein was stoped to the surface for a width of about 8 feet and for about 200 feet along strike.

O. H. BASSETT MINE

The O. H. Bassett mine (10) is in sec. 4, T. 8 N., R. 5 W. An adit 250 feet long follows a vein that strikes N. 75° W. and dips 80° S. The vein, from 6 inches to 2 feet wide, contains abundant pyrite and arsenopyrite with some galena and sphalerite in a gangue of quartz and tourmaline. The alteration zone bordering the vein ranges from 5 to 10 feet in width.

LEXINGTON MINE

The Lexington mine (11), in sec. 4, T. 8 N., R. 5 W., was worked in the early days of mining. According to Pardee and Schrader (1933, p. 252), in 1888 and 1889 the mine produced 2,912 tons of ore that contained about 0.21 ounce of gold and 29 ounces of silver per ton, and 10 percent lead.

The vein zone can be traced on the surface by adits and many shallow pits from the western adit, at altitude 6,020 feet, eastward across a ridge for more than 1,000 feet to the eastern adit, on the west side of a small gulch. The vein in the western adit is 6 to 10 feet wide, strikes N. 78° W., dips 75°–80° S., and has been stoped both above and below the adit level for nearly 100 feet along strike. Ore taken from the stope contained galena, sphalerite, pyrite, and arsenopyrite in a gangue of quartz and tourmaline. In the eastern adit the main vein strikes N. 65° E., and from it many strands of gouge branch to the northeast. The rock is intensely broken because of movement on the Red Mountain fault, which probably occupies the small north-trending gulch at the adit portal.

About 100 feet north of the Lexington vein and parallel to it is a silicified and iron-stained zone about 10 to 20 feet wide.

DANIEL STANTON MINE

The Daniel Stanton mine (12) in sec. 5, T. 8 N., R. 5 W., was worked before 1900. Some shipments were made in 1926 and 1927. The mine consists of 2 adit levels connected by raises and 3 stopes. During the course of the present study uranium was found on the lower dump, and the lower adit was reopened by Mr. J. S. Hampton.

The vein in the lower adit (pl. 9) is virtually a zone of altered rock, some of which has been mineralized. The zone strikes east and dips 75° S. From the center outward, it consists of (1) a medial joint plane, (2) rock altered largely to sericite, and (3) rock altered largely to clay. The joint plane was the controlling structure and served as a channelway for hydrothermal solutions that produced the alteration; in some places along the vein zone, hydrothermal solutions have deposited milky quartz and sulfide minerals—chiefly coarse-grained galena, dark-brown to black sphalerite, and pyrite—by replacing the rock immediately adjacent to the channelway. The sericitized rock is strong and tough and stands quite well, and the original texture of the quartz monzonite is preserved. The alteration zones vary considerably in width along the drift. On the north wall 25 feet west of the second raise the clay zone is only about a quarter of an inch wide and the sericite zone is 4 feet wide, but on the south wall 45 feet west of the first raise the clay zone is at least 5 feet wide and the nearest sericite band is only a few inches wide. Within the vein zone are many somewhat discontinuous joints that strike subparallel to the strike of the zone. They branch from the main band of sericite alteration, and all are bordered by narrow sericite bands and wider clay bands.

Radioactivity.—Radioactivity in the Daniel Stanton mine is restricted to the lower adit, where the vein is radioactive at three places. Radioactivity detected both on the dump and in the mine bears little relation to the amount of uranium present. In the small stope 125 feet from the portal, material containing 0.48 percent uranium gave a reading on a Geiger counter of 0.10 mr per hour, whereas material containing only 0.02 percent uranium registered 0.2 mr per hour. The uranium is not concentrated in the mineralized part of the vein zone but is in the outer part of the sericite band near the zone of clay alteration. Some pieces of sericitized rock from the dump contained 0.26 percent uranium, probably in stringers of black, very fine grained, siliceous material that cut the rock.

BUNKER HILL MINE

The Bunker Hill mine (13) is in secs. 4 and 5, T. 8 N., R. 5 W. Three main adit drifts follow the vein zone in places along a horizontal distance of 1,200 feet and a vertical distance of 600 feet.

According to Pardee and Schrader (1933, p. 253), the mine was worked in the late 1880's and early 1890's and produced 1,272 tons of ore that contained 0.22 ounce of gold per ton, 30 ounces of silver per ton, and 11 percent lead. In 1929 the lower (No. 1) adit was driven from the valley of Tenmile Creek. Two small stopes from the No. 1 adit yielded nearly 400 tons of ore that contained about 0.5 ounce of gold and 14 ounces of silver to the ton, 9 percent lead, and 5 percent zinc. In 1947 about 891 tons of ore was mined from a flat stope near the face of the No. 2 adit (alt. 6,000 ft). This ore contained about 0.15 ounce of gold per ton, 20 ounces of silver to the ton, 5 percent lead, 2 percent zinc, and a little copper. The ore from both the No. 1 and No. 2 adits contained a few percent arsenic.

In the No. 1 adit drift (fig. 36) the vein zone is narrow and undisturbed by postmineralization movement. The mineralized part of the zone is 3 feet or less in width and is generally bounded on each side by strong parallel joints. No single joint continues for a great distance, but where one begins to die out along strike, a parallel joint nearby becomes stronger so that structural continuity of the zone is preserved. Details of the structure of the zone can be clearly seen near the western end of a stope 70 feet long in the No. 1 adit, where two strong parallel joints 2 to 6 feet apart contain narrow veins of quartz and sulfide minerals but no tourmaline. The rock between the veins is intensely altered to sericite; it contains some disseminated sulfide minerals and is ore where the disseminated sulfides are abundant. East of the stope the hanging wall and footwall quartz veins become thinner and die out, and the rock between them is less intensely altered. Farther east the structure is indicated only by two strong joints that die out eastward, and farther along strike there is no indication of the vein zone.

In the No. 2 adit, which is about 400 feet long, the controlling joints are less continuous than in the No. 1 adit. A quartz-tourmaline vein 5 feet wide at the portal narrows to 1 foot where it goes into the south wall 240 feet east of the portal. Exposed in a crosscut a few feet to the north of the adit is a second vein composed of a few stringers in an altered zone several feet wide; 70 feet east of the crosscut, where the first vein narrows to 1 foot, the stringers of the second vein widen and merge to form a strong quartz-tourmaline vein 6 feet wide that continues eastward to a caved stope. The two veins are separated by 5 feet of altered rock. Near the face of the adit drift about 400 feet from the portal the vein dips 80° S. to 90°, but in a raise about 30 feet above the drift the dip flattens. Accordings to Mr. J. S. Hampton, who mined from this raise, the vein continues to flatten upward until the dip is as low as 20° S.

A short distance above the No. 3 adit (alt 6,200 ft), where an old stope has caved through to the surface, several branches of the vein are exposed in a short adit. The main vein from the stope continues eastward but flattens up dip. Several smaller veins branch from the main vein and also flatten a short distance from it.

Vein material on the dump of the No. 2 adit contains black tourmaline, milky quartz, coarse galena, sphalerite and pyrite, and some chalcopyrite and tetrahedrite. Fine-grained tourmaline is cut by veinlets of coarser tourmaline. The tourmaline is in turn cut by veinlets of (1) galena, sphalerite, and pyrite, (2) arsenopyrite, and (3) milky quartz. Some milky quartz veinlets cut galena-sphalerite-pyrite veinlets. Much of the milky quartz is coarsely crystalline and tends to be deposited in comb structure.

The vein zone in the No. 2 adit seems to have been the main channelway for hydrothermal solutions. There, both the vein and the altered zone are widest, and the structure consists of many subparallel and overlapping joints along which the rock is either mineralized or strongly altered. The thin fractures in the No. 1 adit to the west probably were not permeable paths for hydrothermal solutions.

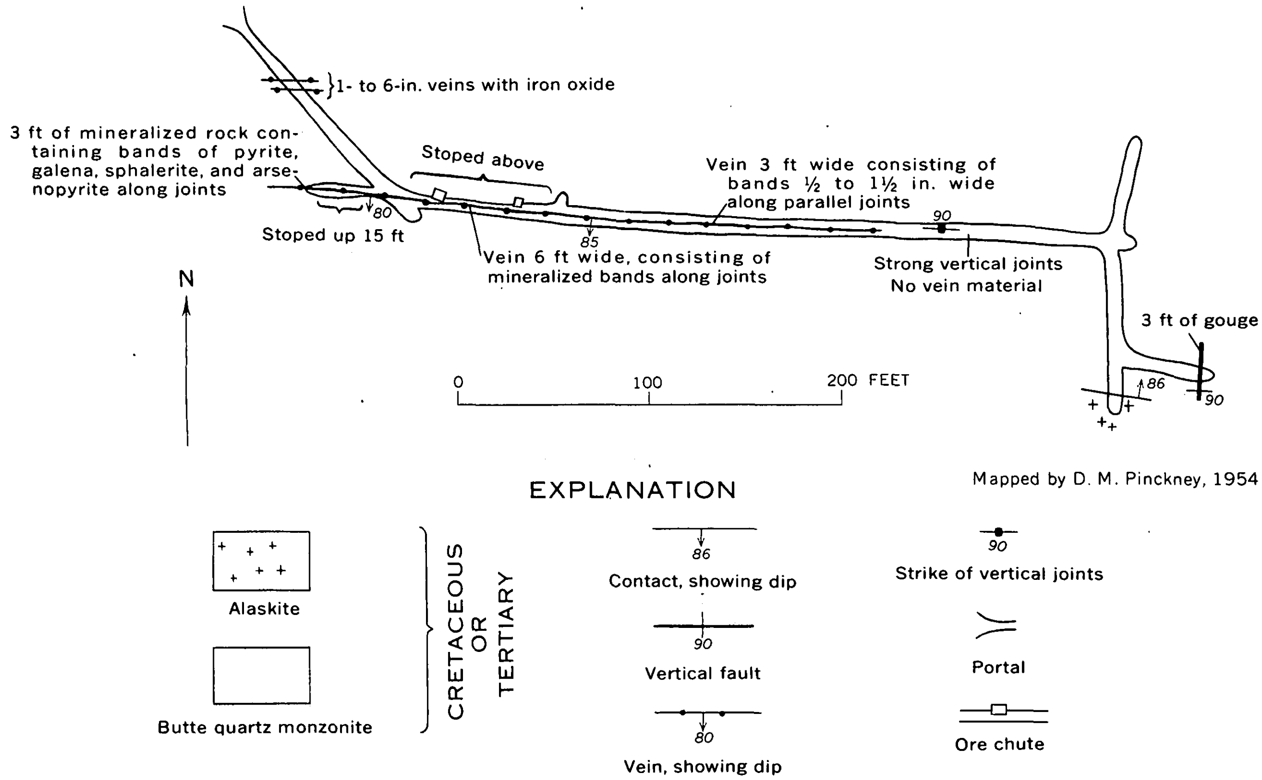

FIGURE 36.—Geologic map of the lower (No. 1) adit, Bunker Hill mine, Rimini, Mont.

TEAL LAKE MINE

The Teal Lake mine (14) is in sec. 5, T. 8 N., R. 5 W. According to an old report, the mine produced 14 tons of ore containing 0.24 ounce of gold per ton, 42 ounces of silver per ton, 17 percent lead, and 4 percent zinc (Pardee and Schrader, 1933, p. 253). A strong quartz-tourmaline vein, 4 to 6 feet wide, containing some sulfide minerals is exposed in a short adit, but its extent is not known. The Teal Lake vein is about 100 feet south of the Bunker Hill vein and could easily be tested by short holes or crosscuts driven from sites in the Bunker Hill No. 2 adit workings.

EVERGREEN MINE

The Evergreen mine (15) is on the east side of Banner Creek in sec. 5, T. 8 N., R. 5 W. During the early days of mining, an adit was driven into the vein zone but no ore was found. In 1942 another adit (alt 5,850 ft) was driven on the vein and an ore body about 85 feet long and 10 feet wide was found. A level was then driven about 100 feet lower and ore was stoped between the two levels and to a point about 50 feet above the upper level.

A total of 3,475 tons of ore was shipped from this ore body, of which 655 tons, considered to be representative, contained 0.29 ounce of gold and 20.2 ounces of silver per ton, 13.4 percent lead, 5.4 percent zinc, 5 percent arsenic, and about 0.5 percent copper.

The vein zone strikes N. 70° W., dips about 80° S., and is composed of several unconnected but overlapping veins, chiefly of quartz and sulfide minerals, in intensely altered quartz monzonite. Tourmaline occurs only in small scattered bunches along the veins. Movement of the walls along the vein zone has produced discontinuous strands of gouge, most of which are in the altered rock rather than in the vein material.

In the lower adit about 100 feet west of the ore body, a wide band of sulfide minerals disseminated in intensely sericitized rock trends N. 75° E. across the vein zone. This band, which contains galena, sphalerite, and pyrite, and ranges in width from 1 foot to 10 feet, has not been explored. It does not seem to be along a controlling structure and may be an irregular pod beside the vein. According to Mr. J. S. Hampton, who operated the mine, the ore body in the vein contained horses of altered wallrock, and in several places ore occurred as disseminations in the horses or in the walls.

The most abundant ore mineral is galena; black spalerite and coarse subhedral pyrite and arsenopyrite are common; tourmaline is rare. In a few places the ore contained bands of milky comb quartz with some chalcopyrite and tetrahedrite and was very rich in silver.

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The weathered and altered rock in the Evergreen vein zone is slightly radioactive for about 300 feet east of the road along the side of Red Mountain above the upper adit.

ALLEY MINE

The Alley mine (16), in sec. 8, T. 8 N., R. 5 W., consists of a shallow shaft, two adit crosscuts, and drifts that follow a strong tourmaline-quartz vein zone. Its history is unknown, and the shaft and western crosscut are both caved and inaccessible.

A drift extending eastward from the eastern crosscut follows the vein zone for 370 feet (fig. 37). The zone strikes N. 73° W. and dips 75°–87° N. between walls of altered quartz monzonite. Tourmaline-quartz veins within the zone are as much as 10 feet wide and are separated from each other by as much as 10 feet of altered rock and fault gouge. The veins are arranged in a closely overlapping en echelon manner, the strike of individual veins diverging 10° to 20° from the strike of the vein zone. Near the center of the vein zone the veins change strike, so that they are parallel to the zone, or they trend at a very low angle across the central part of the zone and diverge from it on the edge, where they apparently die out. The maximum width of two main veins in the accessible part of the eastern adit is about 12 feet. Short crosscuts to the south of the mineralized zone expose 14 feet of altered rock and do not reach unaltered rock.

In the eastern end of the accessible workings the vein zone is offset about 60 feet to the north by a fault that strikes northeast and dips steeply to the west. A drift eastward on the offset segment of the vein zone is caved. The fault is a zone 10 feet wide in the drift. A vein of fine-grained quartz 4 to 6 inches wide within the fault zone is not sheared and appears to be younger than the fault.

The most abundant minerals at the Alley mine are tourmaline and quartz. Small amounts of galena, sphalerite, pyrite, arsenopyrite, and chalcopyrite are in veinlets that cut the tourmaline and quartz. Thin chalcedony veinlets cut all the other minerals.

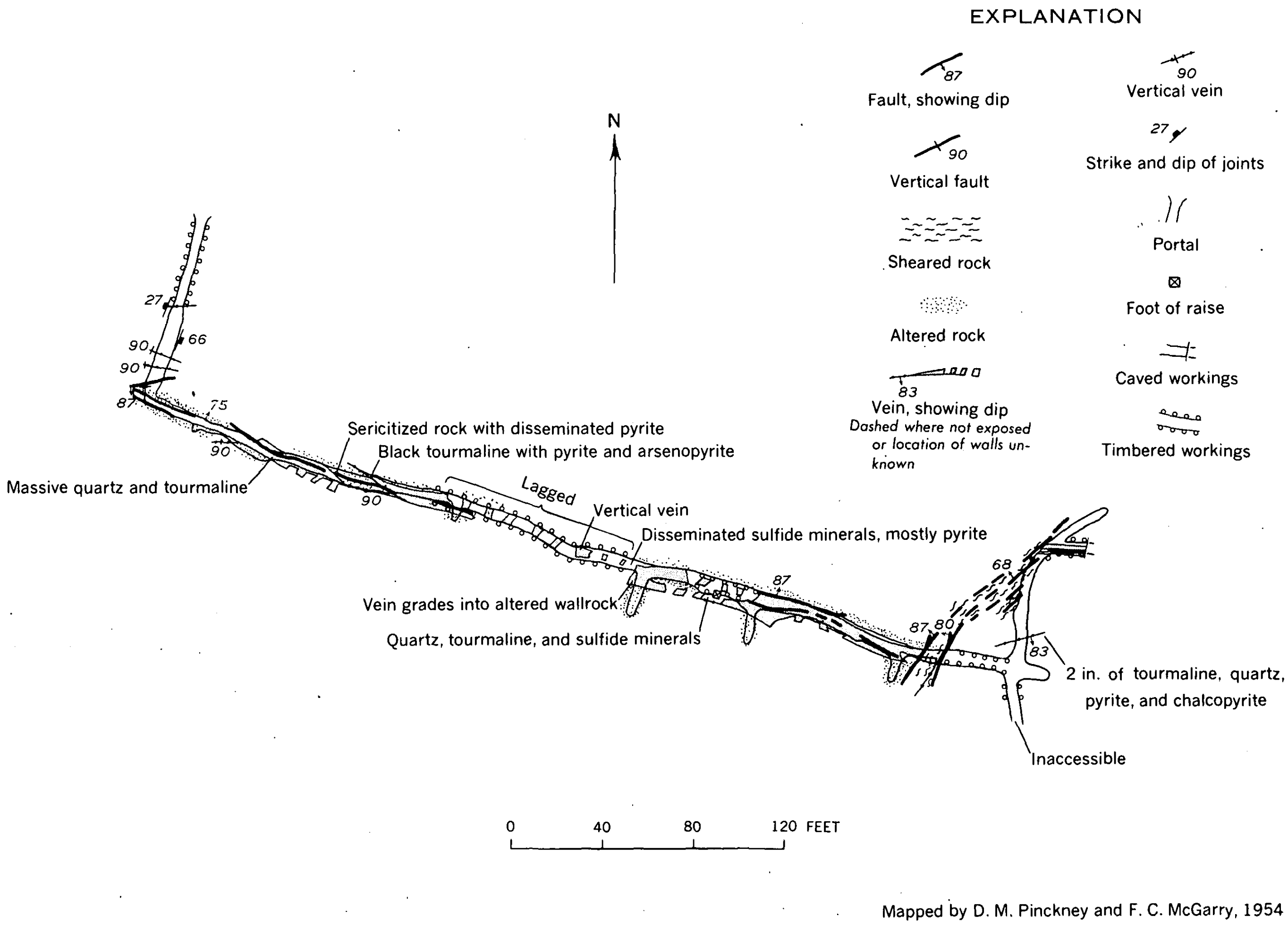


Figure 37.—Geologic map of accessible parts of the Alley mine, Rimini, Mont.

LOCALITY 5

A prospect shaft (5) in sec. 34, T. 9 N., R. 5 W., exposes a milky quartz vein that is barren of sulfide minerals but is bordered by intensely sericitized fl containing disseminated meta-autunite. A selected sample of the altered fl contained 0.073 percent uranium. A zone 5 to 10 feet wide of relatively high radioactivity trends northeastward for a short distance from a point about 20 feet west of the shaft.

MINES IN THE SOUTHERN AREA

HORSEFLY ADIT

A quartz vein 3 feet wide is exposed at the caved portal of the Horsefly adit (17) in sec. 10, T. 8 N., R. 5 W. The attitude of the vein is N. 85° E., 65° S., and it is enclosed in intensely altered walls of quartz monzonite, about 150 feet below the rhyolite on Red Mountain. Pieces of vein material on the dump are mostly milky and bluish-gray quartz containing irregular bands and pods of pyrite. The entire dump is slightly radioactive. A stream of water issuing from the adit is more highly radioactive than the dump, which suggests that uranium is being leached from the vein or possibly from the overlying rhyolite and carried away by the mine water.

LOCALITY 18

A steeply dipping quartz vein that strikes eastward for about 1 mile in sec. 21, T. 8 N., R. 5 W., was mined by a crosscut near its eastern end, a shallow shaft, and several pits and adits (18). The primary vein minerals are quartz, pyrite, arsenopyrite, sphalerite, and galena. The wallrock is intensely altered to sericite and contains disseminated pyrite. For 1,500 to 2,000 feet east of the creek, the vein is thoroughly oxidized to a brick-red siliceous boxwork that contains much hematite, is cut by chalcedony stringers, and is radioactive. A sample of the most radioactive material contained 0.65 percent uranium; no relation was found between the amount of chalcedony and the amount of radioactivity. West of the road the vein is largely unoxidized and contains milky to blue-gray quartz and pyrite with some sphalerite and galena. The intensely oxidized part of the vein probably was originally composed chiefly of pyrite. No secondary minerals that would indicate the former presence of other sulfide minerals were found. East of the thoroughly oxidized area the vein is only slightly radioactive.

PEERLESS JENNIE MINE

The Peerless Jennie mine (19), in sec. 21, T. 8 N., R. 5 W., is one of the larger mines in the Rimini district; it was worked almost entirely in the early days of mining, mainly for silver. According to Knopf (1913, p. 84), the surface ores were very rich, containing as much as 900 ounces of silver per ton. During the 1920's and 1930's the mine produced a very small amount of ore (U.S. Bur. Mines, 1925–27; 1938–39), some of which probably was shipped from the dumps.

The main workings are a shaft of unknown depth, a long crosscut south to the vein, drifts to the east and west from the crosscut, and a raise from the crosscut. A flooded winze of unkown depth extends below the crosscut north of the vein.

The strong, altered and mineralized zone at the Peerless Jennie mine strikes N. 70° W. and dips 70° N. It is traceable on the surface for 1 mile as a wide, altered, and weathered zone locally stained with hematite or marked by quartz outcrops. The vein zone is intensely crushed, sericitized, and impregnated with small pyrite cubes, and it contains stringers of quartz (Knopf, 1913, p. 84).

CRESCENT AND IDA MAY MINES

The Crescent mine (20), in sec. 9, T. 8 N., R. 5 W., and the Ida May mine (21), in sec. 28, T. 8 N., R. 5 W., probably worked veins in the same vein zone. Both mines were worked in the 1890's; the Crescent mine was worked again in the 1950's by W. A. Hall of Helena, and a flotation mill was built in 1954. No production records are available, but both mines are apparently fairly large.

At the Crescent mine three veins were worked by an adit 500 feet long and stopes totaling more than 300 feet in length above the adit level; a winze near the portal of the adit is 75 feet deep but flooded (fig. 38). Two main veins about 25 feet apart on the adit level strike about N. 70° W. and dip to the south. The northern vein dips more gently than the southern vein, so they may intersect below the adit level. About 380 feet west of the portal the southern vein begins to change strike and at the face of the drift it strikes N. 75° E. A third vein, which dips 35° S. and extends N. 67° E. from a point near where the southern vein starts to change strike should intersect the northern vein a few feet beyond the western face of the drift that follows the northern vein.

The Ida May shaft (21) is in a marshy area about ¾ of a mile east of the Crescent mine. The shaft is flooded to its collar, but a large low dump indicates considerable underground workings. A quartz vein trends about N. 80° W. Dump material indicates that the vein probably consists of altered rock cut by bands and stringers of vein material—mostly coarse dark-brown sphalerite and milky comb quartz with a minor amount of limonite and manganese oxide stain. The entire dump is slightly radioactive.

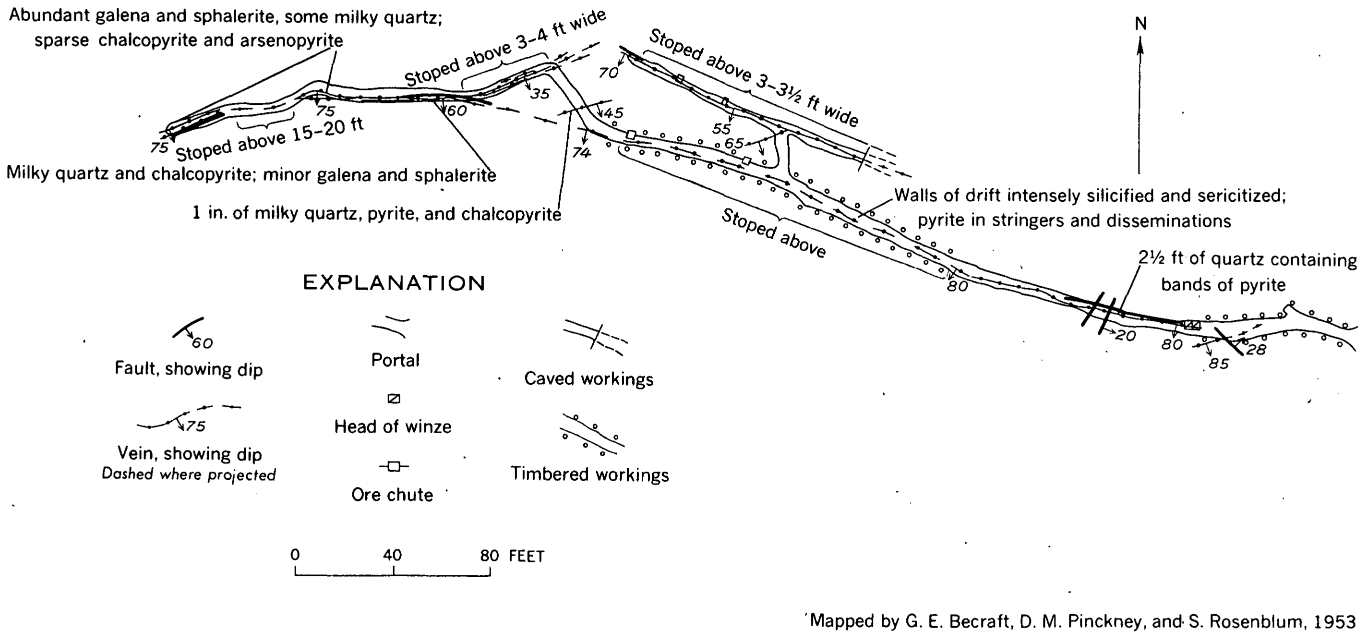


FIGURE 38.—Geologic map of the Crescent mine, Rimini, Mont.

A shallow shaft 1,000 feet S. 80° E. of the Ida May shaft exposes a vein 3 feet wide containing mostly sphalerite and milky quartz, as at the Ida May shaft, but containing also some galena and brown chalcedony. Both galena and sphalerite are cut and replaced by veinlets and irregular bodies of milky quartz.

FROHNER–NELLIE GRANT MINES

Several mines have worked veins in intensely sericitized fine- to medium-grained Butte quartz monzonite along a zone that trends northwestward for more than half a mile in secs. 14 and 15, T. 8 N., R. 5 W. Both the Frohner mine (22) and the Nellie Grant mine (24) appear to have been idle for many years, and little information is available about their history, production, or size.

According to W. H. Weed (written communication, 1897), the Frohner mine was closed in 1893. It was reportedly developed mainly by an adit 1,120 feet long, now caved at the portal, and a cribbed ore-compartment inclined shaft 700 feet northwest of the adit portal. The shaft is open at the collar, but it is flooded a short distance below. A second "shaft" about 300 feet farther to the northwest probably is a raise to the surface. In 1928 and 1929 two cars of lead ore were produced, probably from a part of the vein just east of the portal of the adit. In 1939 an attempt was made to recover silver from the Frohner dump by use of a small jig mill.

The vein zone, which is not well exposed at the Frohner mine, trends northwestward and dips about 60° S. According to Weed, the zone is about 40 feet wide, but the ore is in "shoots and bunches." From the adit portal the vein zone extends 1,500 feet northwestward and 1,700 feet southeastward; near its southeastern end it strikes more to the east and dips steeply. About 1,000 feet east of the Frohner mine in the same vein zone is a flooded shaft (23), last worked during World War II. The small dump indicates only a few hundred feet of workings.

The Nellie Grant mine (24) is about 500 feet farther to the southeast. In 1953 and 1954 a prospector was opening the vein near the Nellie Grant shaft; there the vein strikes N. 72° W., dips 83° S., and is about 4 feet wide. The hanging wall is a strong plane surface, but the footwall for several feet from the vein is cut by many narrow stringers that branch from the vein and go into the wall. The vein near the shaft is oxidized.

The vein material on the Nellie Grant dump contains pyrite, sphalerite, galena, gray to white quartz, and some chalcedony; it is characterized by an abundance of coarse pyrite and coarse milky quartz, both of which occur mostly as subhedral to euhedral crystals. Lesser amounts of very dark brown sphalerite and galena are present. Sphalerite is more abundant than galena, but the ore may have been hand sorted and the sphalerite discarded. Much of the galena and sphalerite has been sheared and is cut by veinlets of pyrite. White to gray quartz veinlets cut galena, sphalerite, and pyrite and are in turn cut by chalcedony veinlets.

Pyrite is the most abundant sulfide mineral at the Nellie Grant mine, but farther northwestward at locality 23, sphalerite is most abundant, and pyrite and galena occur in lesser amounts. Arsenopyrite, which is completely lacking at the Nellie Grant mine, is by far the most abundant sulfide on the Frohner mine dump. It is closely associated with much milky to gray quartz. Pyrite is next in abundance, disseminated through the wallrock, bunched irregularly, or associated with the quartz and other sulfide minerals. Sphalerite is more abundant on the Frohner dump than galena, they are associated in irregular bands and bunches in the quartz and are both cut by veinlets of quartz and chalcopyrite, some of which follow the cleavage. The sphalerite contains many minute round or elongate blebs of chalcopyrite.

About 400 feet southeast of the Nellie Grant mine is a shallow shaft (25) in a vertical vein that strikes east and consists of stringers across a zone 3 feet wide. The vein material includes milky quartz, commonly in subhedral crystals 1 cm across, much sphalerite and pyrite, and some galena. The wallrock of the vein in the shaft is alaskite. In places the alaskite is altered to clay, but alteration is not extensive.

OTHER MINES

Locality 26

Location.—Sec. 15, T. 8 N., R. 5 W.

Mine workings.—An adit probably a few hundred feet long and two shallow shafts; all inaccessible.

Wallrock.—Medium-grained Butte quartz monzonite, altered to sericite and clay.

Vein.—About 600 feet long; strikes east and dips 55° S.

Mineralogy.—Bands composed of (1) chiefly galena and black sphalerite, some pyrite and quartz, and minor chalcopyrite; (2) quartz, carbonate minerals, and pyrite; and (3) sericitized wallrock.

Locality 27

Location.—Sec. 15, T. 8 N., R. 5 W.

Mine workings.—Four caved adits with moderately large associated dumps.

Vein.—Banded quartz vein 2 to 4 feet wide.

Wallrock.—Fine- to medium-grained Butte quartz monzonite, altered to sericite and clay.

Ore minerals.—Galena, pyrite, and sphalerite.

Gangue.—Milky quartz and altered wallrock.

Panama mine ((28)

Location.—Sec. 22 and 23, T. 8 N., R. 5 W.

History.—Worked in recent years.

Mine workings.—Three adits; probably a few hundred feet of mine workings.

Vein.—Strike, east; dip, 80° S.; composed of bands of sulfide minerals white to light-gray quartz, and carbonate minerals.

Mineralogy.—Galena, sphalerite, pyrite and quartz, brecciated and cemented by primary carbonate minerals, probably in part rhodochrosite.

CLANCY DISTRICT

The Clancy district as used in this report includes the northeastern part of the Jefferson City quadrangle roughly north of Jefferson City and east of Lava Mountain and the Spruce Hills (pl. 1). Also included in the Clancy district of most older reports are the mines in the drainage of Warm Springs creek east of Alhambra, in the Clancy quadrangle. Parts of the Clancy district have been referred to as the Warm Springs, Alhambra, and Lump Gulch districts. Before 1900 the King Solomon mine (39) and the mines along Lump Gulch—particularly the Free Coinage and Little Nell mines (35, 36)—produced very rich silver ores, and a town called Lump Gulch City flourished. Coincident with the World War I rise in the price of metals, production from the Clancy district rose from $5,020 in 1915 to $218,574 in 1920, when the price of silver was established at one dollar an ounce, but it gradually declined to about $3,000 in 1929 (U.S. Geol. Survey, 1915–23; U.S. Bur. Mines, 1924–29). Since 1930 almost no lode mining has been done in the district. Placer gold deposits on Clancy and Prickly Pear Creeks were dredged between 1933 and 1947.

The Clancy district is almost entirely underlain by Butte quartz monzonite and by alaskite. The rocks of the district also include quartz latite dikes of Oligocene age and a few dikes of uncertain age and composition. Structures that trend northeastward predominate. The Clancy district includes one of the two areas where chalcedony veins are abundant in the Jefferson City quadrangle. Many of the veins, such as those at the Argonne mine (31), on King Solomon Ridge (38), and at the G. Washington mine (40), contain small quantities of radioactive material. These uraniferous veins have been investigated by Roberts and Gude (1953a) and Wright and others (1957). Quartz veins are far fewer than chalcedony veins. They contain much more chalcedony than elsewhere, and some are mapped as quartz-chalcedony veins (pl. 1). Chalcedonic parts of such veins at locality 30 and at the Mary Tait prospect (34) are uraniferous.

The quartz veins have accounted for nearly all the ore produced in the district. The ore was valuable chiefly for its high silver content— some of it was worth $870 per ton (Raymond, in Knopf, 1913, p. 107) and much of it contained about 100 ounces of silver per ton. Ore minerals are argentiferous galena and sphalerite, minor pyrite and chalcopyrite, some tetrahedrite, and probably also ruby silver. The sphalerite is mostly dark brown to dark green and not the blackjack variety common in most other quartz veins.

KING SOLOMON MINE

The King Solomon mine (39) is near the head of a small tributary of Clancy Creek in sec. 6, T. 8 N., R. 3 W. Knopf (1913, p. 104–105) described the mine in some detail at a time when siliceous silver ore was being extracted on the 300-foot level for shipment to the smelter at Butte.

The mine was opened by two shafts, 270 feet apart, that are now caved. The western shaft (the older of the two) is about 300 feet deep, and levels extend from it at depths of 50, 100, 150, 200 and 300 feet; the eastern shaft is about 400 feet deep and levels were driven from it at depths of 100, 150, 200, 250, 300 and 400 feet. The 300-foot level connects the shafts.

Each of the shafts was sunk through an ore body, and the total area of vein stoped from the two ore bodies was 86,000 square feet. If the ore averaged 1 foot in width and contained an average of 125 ounces of silver per ton, the mine may have produced about 1 million ounces of silver. Knopf's description indicates that these estimated averages are low.

According to Knopf, who saw the mine underground, the vein zone trends slightly south of west and dips 60° to 70° S., about parallel to a quartz latite dike. In places the dike forms the hanging wall of the vein zone and is sheared, gougy, and altered. We believe that this alteration was probably due to weathering, not hydrothermal solutions. Where crosscut on the 200 level, the dike is 85 feet wide; gouge and shattered batholithic rock, in places 4 feet wide, were found on the hanging-wall side of the dike, as were streaks of rich ore.

The vein zone is 25 feet or more wide on the north side of the dike and consists of veins of high-grade material, totaling at most a few feet in width, in altered quartz monzonite. In some places the veins merge to form high-grade masses of ore 1 to 2 feet thick. Knopf mentions galena, sphalerite, tetrahedrite, locally some molybdenite, and sparse pyrite as the sulfides in the veins. A ribbon of ore 1½ to 8 inches wide, found south of the dike in the crosscut on the 200-foot level, consisted of resinous sphalerite intergrown with tetrahedrite in a quartz gangue. The sulfide minerals found on the dump are brecciated and recemented by both carbonate minerals and fine-grained quartz, some of which is cut by carbonate stringers.

The feldspar in the quartz monzonite has been altered to clay and sericite. A thorough examination of the quartz latite on the dump failed to find any that has been sericitized, although much of it has been converted to a fine gouge.

LITTLE NELL MINE

The Little Nell mine (36) is on the south side of Lump Gulch in sec. 6, T. 8 N., R. 3 W., about 2 miles west of the confluence of Lump Gulch and Prickly Pear Creek. It has been developed by a 500-foot shaft and drifts at 150, 250, 350, and 450 feet below the shaft collar (fig. 39). The mine was principally worked in two periods. Before 1911 the shaft was sunk on the vein to a depth of 500 feet (Knopf, 1913, p. 105), but the Minerals Yearbooks mention no shipments. In 1919 the mine was reopened and additional work was done on the 150 and 450 levels.

The shaft was sunk on an ore body that is known to have been mined for a length of at least 400 feet and from about 60 feet below the surface to the 450 level. Two smaller ore bodies were mined above the 150 level west of the main ore body. The known extent of the stopes indicates that about 7,700 tons of ore was taken from them if the vein averaged 1 foot in width. Available production records indicate that the ore contained more than 100 ounces of silver per ton, which would mean that the mine probably has produced more than 768,000 ounces of silver. Knopf (1913, p. 105) credits the mine with $400,000 worth of ore. Recorded production since 1901 is about 1,000 tons.

The vein, where exposed at the collar of the caved shaft, is a zone 4 to 6 feet wide of altered quartz monzonite containing several quartz veinlets that range in width from ½ inch to 5 inches. It strikes N. 70° E. at the shaft and dips about 85° S. It can be traced northeastward by smaller shafts, pits, and altered rock to the alluvium in Lump Gulch and probably extends discontinuously beyond into the area of the Liverpool mine just east of the quadrangle.

According to Knopf (1913, p. 105), the ore mined from the Little Nell was "argentiferous galena-sphalerite ore in a chalcedonic quartz gangue." Vein minerals on the dump are sphalerite and very fine grained galena in a gangue of carbonates and microcrystalline to coarse-grained quartz; the minerals are in thin subparallel veinlets that cut and replace the altered wallrock, and they are also disseminated in the altered rock. Much of the sphalerite is intergrown with white crystalline quartz, and both galena and sphalerite are cut and replaced by microcrystalline quartz. The sulfide minerals and the quartz are cut and replaced by iron-bearing carbonate minerals.

FREE COINAGE MINE

The Free Coinage mine (35) is in sec. 6, T. 8 N., R. 3 W., on the north side of Lump Gulch about 2½ miles west of its confluence with Prickly Pear Creek. The mine was worked at two different times before 1900,

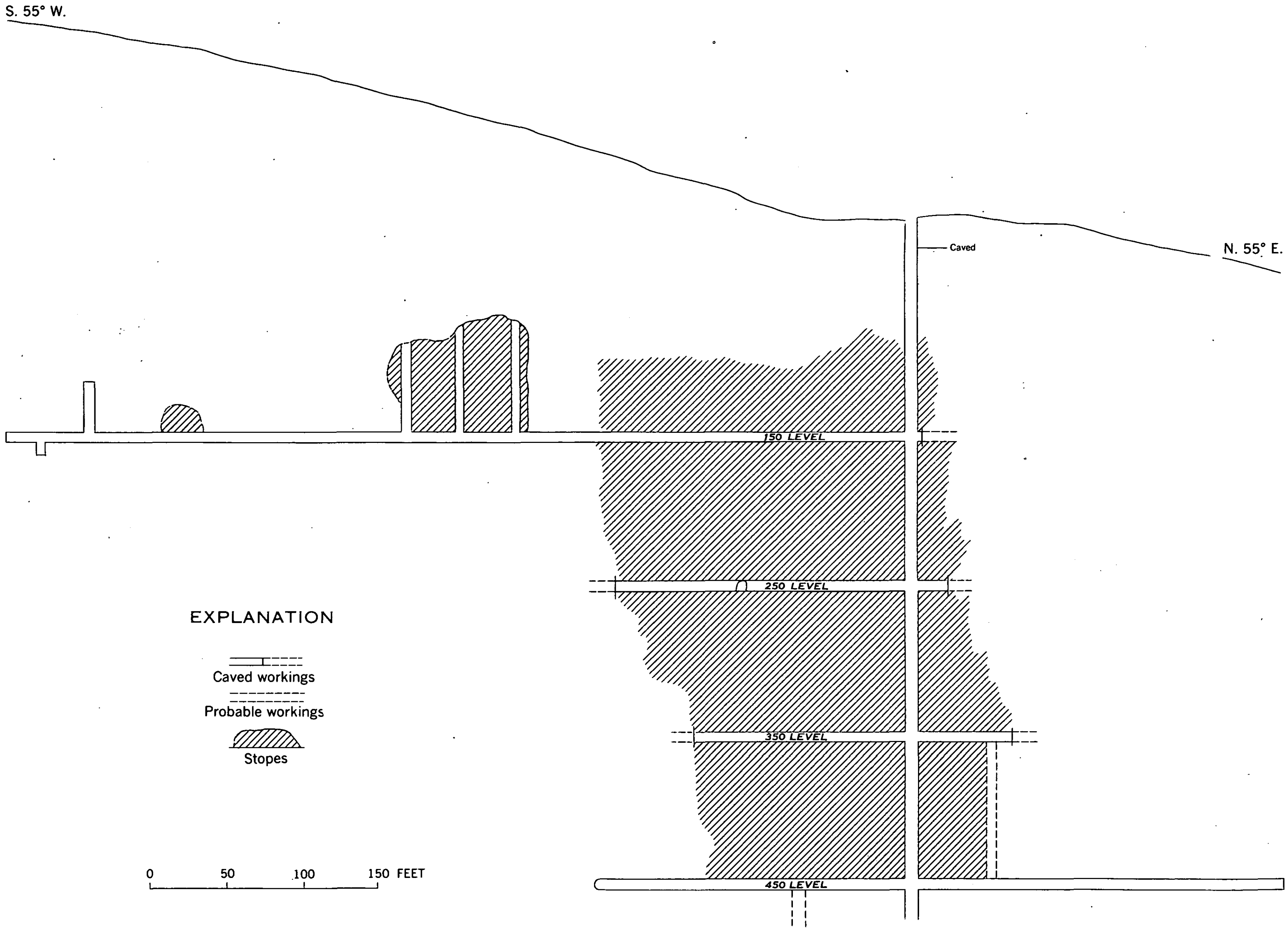


FIGURE 39.—Longitudinal section of the Little Nell mine, Jefferson County, Mont., showing extent of stopes.

and during each period of activity a vertical shaft was sunk. It has been idle since 1900 except for a few years after 1917, when the eastern shaft was deepened and several hundred tons of ore was shipped from small stopes near the shaft. Recorded production since 1901 is less than 1,000 tons.

Ore produced between 1918 and 1920 contained an average of about 70 ounces of silver to the ton, 8 percent lead, and a little gold. The arithmetic average of ore shipped before 1900 from the old shaft is 125 ounces of silver to the ton, 10 percent lead, and 20 percent zinc; and from the new shaft, 137 ounces of silver, 5 percent lead, and 11 percent zinc. An ore body reported to have been worked from the old (western) shaft was stoped for a length of 400 feet and to a depth of 350 feet. If the ore body averaged about 1 foot in width and contained an average of 50 ounces of silver per ton, the mine produced at least 850,000 ounces of silver.

Rock on the dump is cl and a pale pink porphyritic rock found nowhere on the surface nor anywhere else in the quadrangle.

West of the Free Coinage mine, across an interval of about 2,000 feet of alluvium in Lump Gulch, is an iron-stained breccia zone about 1,500 feet long and about 50 feet wide containing some chalcedony. The zone probably is the westward extension of the Free Coinage vein.

MUSKEGON MINE

The Muskegon mine (37) is on the south side of Lump Gulch about 1 mile west of the Little Nell shaft in sec. 1, T. 8 N., R. 4 W. Only a small amount of ore was produced. The outcrop of the vein contains up to 6 inches of crystalline milky quartz and chalcedony in an iron-stained zone as much as 6 feet wide. Some of the wallrock found on the dumps has been altered to sericite. The vein, which strikes N. 72° E. and dips 75° S., was opened by a 200-foot shaft and a 200-foot drift from the bottom of the shaft, and is reported to be as wide as 18 inches in the drift. The Muskegon structure probably extends to and beyond the Free Coinage (9) vein.

MINERAL HILL MINE

The Mineral Hill mine (41) is in a small gulch on the northern side of Clancy Creek in sec. 14, T. 8 N., R. 4 W. It is opened by a short shaft on the top of the hill and an adit about 150 feet below the shaft collar. Two winzes and a 22-foot raise were driven from the 280-foot drift on the adit level (fig. 40).

The vein zone is 5 to 10 feet wide, trends eastward, and dips about 65° to 75° S. At the surface about 500 feet east of the portal of the adit, the vein is an iron-stained zone 6 feet wide that contains tan chalcedony bands up to 4 inches thick and some quartz and sulfide minerals. In the drift (fig. 40) the vein zone contains a few subparallel stringers of quartz and chalcedony accompanied by narrow gouge strands. The quartz veinlets contain a small amount of chalcopyrite. Knopf (1913, p. 105, 106) reports that the ore was chalcopyrite and galena with minor amounts of sphalerite and pyrite.

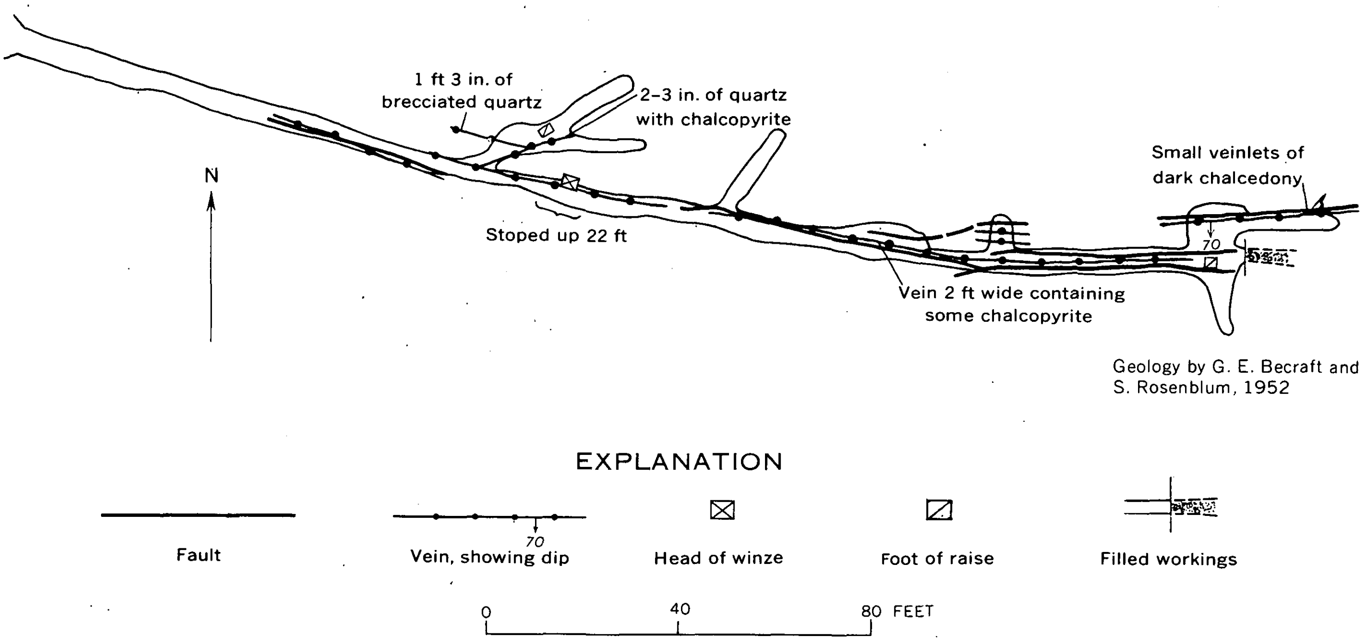


FIGURE 40.—Geologic map of the part of the Mineral Hill mine, Jefferson County, Mont.

LOCALITY 30

A mine at locality 30, on the northern side of Lump Gulch in sec. 13, T. 8 N., R. 5 W., was worked for 50 years before 1953 by a lone prospector who used hand methods entirely. The mine has been developed principally by three adit drifts. Ore was produced from both the No. 1 adit and the No. 3 adit; how much or what kind is not known, except that it probably contained considerable zinc and pyrite.

The vein zone is a complex east-trending zone of faults, veins, and altered rock (fig. 41). Many mineralized veins within the vein zone strike northeastward. All the principal structures dip steeply to the south. The dominant and most widespread alteration of the walls has been to clays, but along most of the wider and stronger veins, the rock has been sericitized immediately adjacent to the vein and altered to clays farther out.

The structure of the main vein is clearly shown in two crosscuts in the western end of the No. 3 adit (fig. 41). The vein is strong and 4 feet wide in one crosscut, but 8 feet to the west in the other crosscut it has split into two thinner veins with intervening altered wallrock. The rock adjacent to the wider part of the vein is intensely sericitized, but the wallrock of the narrower part is less altered. In the eastern crosscut the hanging wall is well defined and is bordered by 4 to 6 inches of sericitized quartz monzonite containing much disseminated pyrite. The footwall is less well defined and contains many quartz stringers in the sericitized rock, which decrease in number away from the vein. About 80 feet east of these crosscuts near the portal of the adit, one branch of the vein consists of numerous quartz stringers in a wide zone with gradational walls. Toward the end of this zone the quartz stringers die out, and the structure continues only a few feet beyond as a few very weak fractures. Most of the vein shown on the map (fig. 41) is barren of ore minerals. Ore bodies were mined along the southwest-trending vein in the No. 3 adit and to the west of the flooded area in the No. 1 adit.

Except for a few thin stringers close to the portal, the vein is completely unoxidized, even where it is very close to the surface in the No. 3 adit. Any oxidized zone that may have existed was removed by glacial ice in Lump Gulch.

Pyrite, sphalerite, galena, and quartz are on the dumps. Pyrite and quartz are closely associated and are the most abundant minerals. The quartz is both a coarse white, milky variety and a microcrystalline black variety. Sphalerite, the second most abundant sulfide, is very dark brown to black, coarsely crystalline, and cut by veinlets of white quartz. The small amount of galena is coarsely crystalline and is associated with the sphalerite. Radioactivity on the dump is greatest in the abundant black microcrystalline quartz; a selected sample analyzed by Maryse Delevaux, U.S. Geological Survey, contained 0.16 percent uranium.

ARGONNE MINE

The Argonne mine (31), in sec. 13, T. 8 N., R. 5 W., one-half mile west of Park Lake, was located in 1931 and worked for gold. During the present investigation high radioactivity and secondary uranium minerals were found on the dump. The mine was partly reopened in 1954 for uranium.

A chalcedony vein zone, which has been opened by an adit, a shaft at the adit portal, and several shallow pits, strikes about N. 75° E. and dips steeply southward, between walls of altered and weathered medium-grained quartz monzonite. The overall width of the vein zone is 4 feet or less, and individual chalcedony veins are as much as 1 foot wide. The vein zone is highly iron stained from the almost complete oxidation of pyrite, which was disseminated in the altered wallrock and the chalcedony. One small stringer of sphalerite was found. The secondary uranium minerals metatorbernite and uranophane are scattered through the altered wallrock and the chalcedony. Selected samples of radioactive material contained:

	Percent U_3O_8	*Percent* eU
Sample 1	0.18	0.19
Sample 2	.12	.13

MARY TAIT PROSPECT

The Mary Tait vein is in sec. 31, T. 9 N., R 3 W. It can be traced intermittently for nearly half a mile. The vein contains limonite, milky quartz, chalcedony, and some barite. In a 30-foot shaft on the east side of a small gulch north of the Free Coinage mine (35), the vein is 1½ feet wide and contains limonite, chalcedony, and milky quartz. The chalcedonic material on the dump is radioactive. A selected sample contained 0.028 percent equivalent uranium and 0.020 percent uranium. The most radioactive material appeared to be the material thrown on the dump most recently.

KING SOLOMON RIDGE GROUP

The King Solomon Ridge group of adits (38) is in sec. 6, T. 8 N., R. 3 W. In 1949 several chalcedony veins in the area were found to be radioactive at the surface and to contain secondary uranium minerals. Some of the silicified zones containing chalcedony veins are as much as 40 feet wide at the surface.

The Forty-niner crosscut, 500 feet long, was driven in 1951–52. It was designed to intersect the downward projection of a wide chalcedony vein zone that strikes

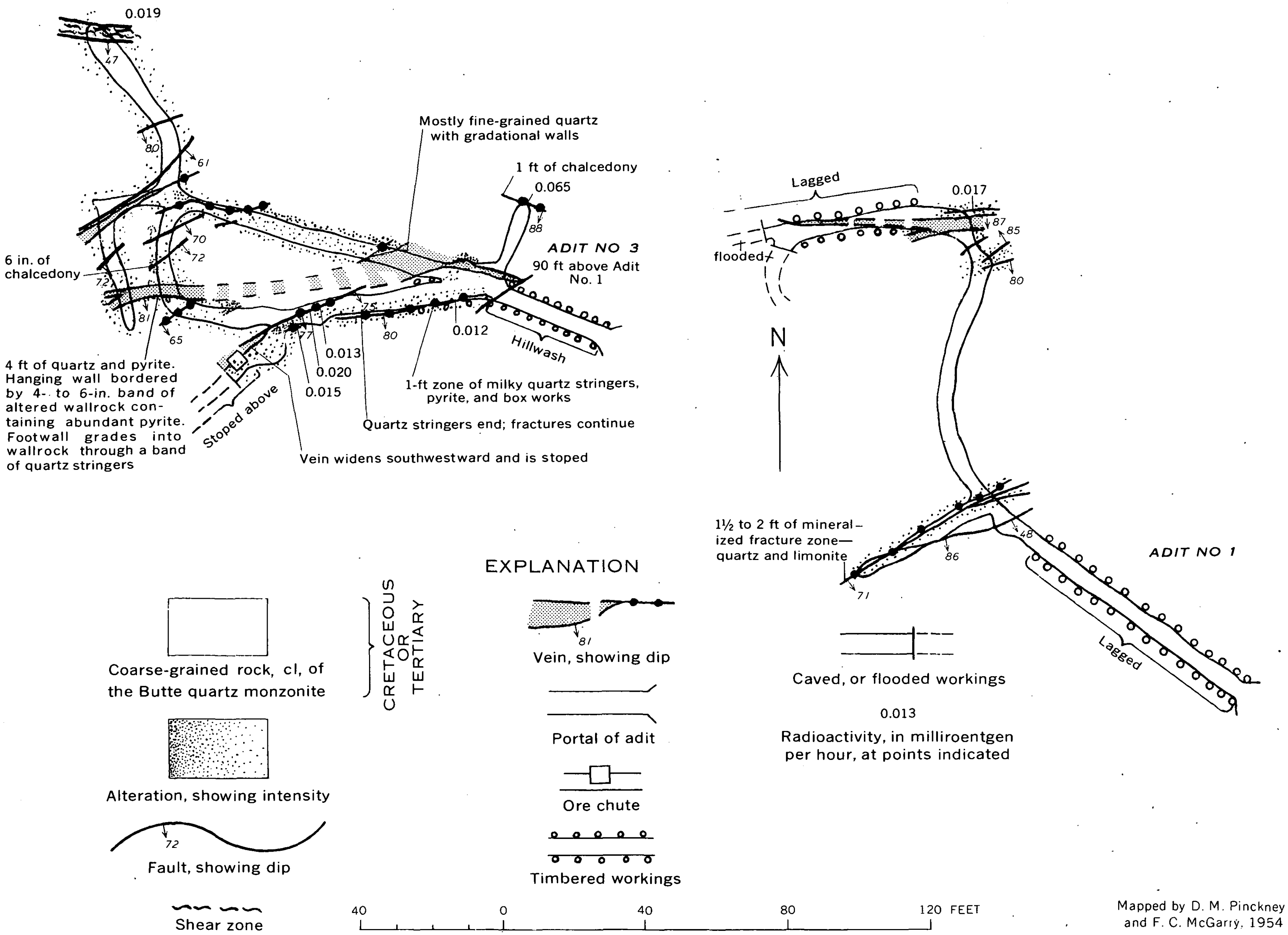


FIGURE 41.—Geologic map of adits at locality 30, Jefferson County, Mont., showing structure of the vein.

nearly east on the surface, but apparently it did not. The downward projection of this zone may be about 60 feet north of the face of the crosscut. Several other chalcedony veins in the crosscut are from a few inches to one foot wide. Two older caved adits near the Forty-niner crosscut are probably short.

G. WASHINGTON MINE

The G. Washington mine (40) is about 1½ miles southwest of Clancy in sec. 17, T. 8 N., R. 3 W., on a chalcedony vein that strikes about N. 80° W. and dips about 80° S. In 1952 a crosscut 195 feet long was driven to reach the vein, and then drifts were cut along the vein for about 140 feet both east and west from the crosscut. A raise extends 75 feet from the drift to the surface. The vein consists of many braided or anastomosing chalcedony veinlets in quartz monzonite that has been altered chiefly to clay and fine-grained silica. In outcrop the vein is about 10 feet wide but in the drift its maximum width is only 3 feet. Toward the western end of the drift the thin branching chalcedony veinlets become indistinct in the altered wallrock and the vein probably dies out. Near the raise the vein contains sparse small metatorbernite crystals.

OTHER MINES

Forest mine (29)

Location.—Sec. 18, T. 8 N., R. 4 W.

History.—Nothing known. Apparently not active for many years.

Mine workings.—Shaft. Large dump indicates extensive underground workings.

Vein.—Nowhere exposed.

Ore minerals.—Galena, sphalerite, pyrite, and chalcopyrite.

Gangue.—Coarsely crystalline milky quartz.

Alteration.—Mostly clays; some sericite.

Radioactivity.—Part of the dump is weakly radioactive.

Locality 32

Location.—Northeast corner of quadrangle in sec. 32, T. 9 N., R. 3 W.

Mine workings.—Several shallow shafts and short adits. A shaft at altitude 4,840 feet probably connects with several hundred feet of workings.

Vein.—Quartz-chalcedony vein up to 2 feet wide exposed in shaft; strikes N. 60° E. and dips 86° S. Largely oxidized. Segments of the vein on the surface are mostly chalcedony.

Mineralogy.—Light-green to brown sphalerite, galena, sparse pyrite, and secondary copper minerals.

Gangue.—Chalcedony, quartz, primary carbonates.

Roosevelt mine (33)

Location.—A mile north of Lump Gulch in sec. 31, T. 9 N., R. 3 W.

Mine workings.—2 shafts, now caved. Dumps indicate several hundred feet of workings.

Vein.—N. 80° E., 70° S. Galena, greenish sphalerite, pyrite, in gangue of white crystalline quartz, calcite, siderite, and chalcedony. White chalcedony is brecciated and replaced by brown chalcedony.

Wallrock.—Coarse-grained quartz monzonite altered to sericite.

WICKES (COLORADO) DISTRICT

The area referred to in this report as the Wickes mining district extends from the South Fork of Quartz Creek on the north to near the head of Spring Creek on the south, and from the Occidental Plateau on the west to the east edge of the quadrangle (pl. 1). The mining district includes the mining camps of Wickes, Corbin, Gregory, the town of Jefferson City, and the seldom-recognized Golconda district around Golconda Creek. All-weather transportation for the mines in the district is provided by the Great Northern Railroad, over which ore can be shipped directly to the East Helena smelter, and also by U.S. Highway 91 and several graded gravel roads. The Wickes district was formerly called the Colorado district.

The most productive mine in the Jefferson City quadrangle, the Alta silver-lead mine, is in the Wickes district, and three other mines in the district each produced ore valued at more than $1 million. The Alta (67), Gregory (63), Minah (49), and Mt. Washington (46) mines are credited with a total production of about $41,500,000 before 1900. Recorded production from the entire district since 1900 is valued at $5,850,470.

Butte quartz monzonite and late-stage rocks of the batholith underlie most of the northern and eastern parts of the district, and Elkhorn Mountains volcanics underlies much of the central, western, and southwestern parts. In the central part of the district, tuffaceous rocks of the Lowland Creek volcanics of Oligocene age overlies the Elkhorn Mountains volcanics, and both units are cut by steeply dipping dikes and irregular intrusive bodies of quartz latite. Several well-defined shear structures trend eastward, dip steeply, and contain ore-bearing quartz veins; the structures are probably more persistent than shown on plate 1, inasmuch as parts of them are probably concealed by the younger quartz latite tuff and by gravels and soil.

Quartz veins are the strongest and most numerous type of veins in the district, and almost all of the ore has come from them. A little ore has been produced from quartz-chalcedony veins, including a small amount of uranium ore at the Lone Eagle mine (42). The most productive veins trend nearly east and contain silver-lead ore bodies composed largely of galena, sphalerite, pyrite, and quartz. Quartz veins east of the longitude of the top of Alta Mountain trend northeast rather than east, and their dominant mineral assemblage is quartz, pyrite, and chalcopyrite. Most of these northeast-trending veins are narrow and have produced little ore. In and near sec. 9, T. 7 N., R. 4 W., the northeast-trending quartz veins die out near the edge of the northern area of chalcedony veins.

Two faults cut the rocks in the Wickes district. One is parallel to the east-trending veins and shear zones, and the other is parallel to the northeast- and north-trending quartz latite dikes. Another persistent lineament, the controlling structure of which is not known, extends north-eastward through the district. The lineament is followed by Spring Creek from its source to Prickly Pear Creek; southwest of the Wickes district the structure is marked by the upper part of High Ore Creek, the High Ore vein in secs. 2, 3, and 10, T. 6 N., R. 5 W., and a straight segment of Big Limber Gulch in sec. 9, T. 6 N., R. 5 W. About half a mile northwest of this lineament another shorter and nearly parallel lineament is followed by the lower part of Wood Chute Creek west of Wickes. These lineaments and most of the steeply dipping structures in the district approach each other in the vicinity of Alta Mountain, and this is the area of the largest ore deposit in the northern part of the batholith, the Alta deposit.

ALTA MINE

The most productive silver-lead mine in the Jefferson City quadrangle, the Alta mine (67), is in sec. 10, T. 7 N., R. 4 W. The ore body was discovered in 1869, and the mine was operated until 1882 or 1883 by the Alta Montana Co. This operation failed, partly because high freight rates required that the ore mined be worth at least $100 per ton. In 1883 the mine was bought at public auction by S. T. Hauser and D. C. Corbin, who also purchased the Comet mine (100) and organized the Helena and Livingston Smelting and Reduction Co. A concentrator was built at the Alta mine and the smelter at Wickes was enlarged. During this period, between 150 and 200 tons of ore was mined per day from the Alta. By 1889 most of the ore above the main haulage level had been extracted, and by 1894 a winze had been sunk 600 feet (Montana Inspector of Mines, 1889, p. 102–105; 1894, p. 71). In April 1896 the mine was closed, and the smelter was moved to East Helena. The high cost of mining below the main haulage level, the drop in the price of silver in 1893, and the tailings losses at the concentrator were major factors in the closing.

The mine has been reopened twice since 1896, but little ore has been mined. In 1909 the Alta mine was taken over by the Boston and Alta Mining Co., the Dick shaft was sunk 600 feet, and some level work was done; this operation was suspended in 1910 (Knopf, 1913, p. 109) without producing any ore. In 1919 L. S. Ropes, of Helena, reopened the shaft and did some drifting and crosscutting but produced no ore. Other underground work done since 1896 has been mostly by lessees in the upper levels. From 1950 through 1956 the Lahey Leasing Co. has been mining low-grade ore from an open pit at the apex of the ore body. This material is used as silica flux in the smelter at East Helena.

The tailings from the old Alta concentrator have been reworked successfully three times. During the nineties the tailings were re-treated in a more efficient concentrator, and from 1925 to 1927 the tailings from this concentrator were re-treated by flotation. A second flotation plant operated from 1938 to 1941 and re-treated the tailings from the first flotation plant.

The mine is thought to have produced more than 1¼ million tons of ore valued at $32 million before 1893 (U.S. Geol. Survey, 1909, p. 374); recorded production is 997,650 tons (Billingsley and Grimes, 1918, fig. 19, p. 353). About 10,000 tons of ore was produced between 1901 and 1948, and nearly 250,000 tons of tailings were re-treated during the last two milling operations. An estimated few hundred thousand tons have been mined from the open pit for use as silica flux.

The Alta ore body was mined by a shaft 665 feet deep and 13 levels through a vertical interval of 1370 feet. Levels 2, 4, 6, and 8, which were the main working levels, open to the surface on the eastern side of Alta Mountain. Dick shaft is near the portal of the main haulage level, No. 8. Level 12 and higher levels are connected by several raises or winzes, and levels 12 and 13 are connected by a raise west of the shaft. No. 13 connects to the bottom of the shaft and was driven during the last operation of the mine. The shaft is in good condition above water level but is flooded 100 feet below the collar; nearly all the workings are inaccessible. Recent work has been open-pit mining.

The deposit is in a well-defined east-trending shear zone, along which rocks of the Elkhorn Mountains volcanics are fractured and intensely altered for widths of 150 to 200 feet. Although very near the contact between volcanic rocks and rocks of the batholith, the shear zone is apparently almost entirely in the volcanic rocks down to the deepest level of the mine—a vertical depth of 1,370 feet. The zone dips 30°–60° N. in the Upper levels of the mine and 60°–70° N. in the lower levels. It extends westward under the Lowland

Creek volcanics west of Alta Mountain, but east of the No. 8 portal it probably dies out. A quartz latite dike cuts the Alta ore body in the open pit, and a second dike has been intruded along or very near the ore body near the No. 8 portal.

The Alta ore body is about 1,600 feet long and has been mined to a depth of about 1,400 feet below the outcrop. It apparently consists of large overlapping lenses, veins and replacement bodies, made up mostly of ore minerals—galena, pyrite, tetrahedrite, and minor sphalerite—in three major ore shoots. According to old maps, these ore shoots are 250 to 400 feet long along strike and extend downdip from near the surface; they are separated by lean, unmined zones 100 to 150 feet long. Material on the dumps indicates that the gangue is mainly altered wallrock instead of the low-grade siliceous vein material that characterizes many of the other deposits.

Parts of the ore body are oxidized, but the extent of oxidation is not known. The ore in the open pit at the apex of the vein is very low grade, and the ore may be intensely leached to a depth of 150 feet on the top of Alta Mountain and to lesser depths on the eastern slope. Old maps show that ore was mined up to about the altitude of the No. 1 level but not above, which suggests that the ore above the No. 1 level and under the pit was low grade and possibly leached. Ore in limited underground exposures near the No. 2 portal is completely oxidized and contains a little silver and lead; about 150 feet lower, above the portal of the No. 4 level, the ore body contains about 50 ounces of silver per ton and some lead, zinc, and copper. Vein material on the dumps from the No. 4 and lower levels is not oxidized, and presumably oxidation is restricted to near the surface.

Available records give incomplete data about the tenor of the ore. Smelter and shipment records for a 5½-year period from 1889 to 1894 show that some ore contained 0.13 ounce of gold and 105 ounces of silver per ton and 50 percent lead, but most lots of crude ore contained about 0.10 ounce of gold, 20 to 50 ounces of silver and 18 to 35 percent lead. Nearly all ore mined during this period was concentrated and probably was lower grade. The ratio of concentration is not known, but the concentrates contained about as much metal as most of the lots of crude ore. In addition, many lots of concentrates contained about 12 percent zinc.

An area underlain by Elkhorn Mountains volcanics and extending several hundred feet north and west of the Alta shaft is altered and, in places, iron stained. Several oxidized veins that strike N. 65° E. and dip steeply are exposed in pits and trenches in this area. None of these veins have been explored except in adits that penetrate only a short distance below the surface. The now-caved Grandfather adit (68), near the Alta shaft, extends about 80 feet northwestward to a vein thought to be a few feet wide; material from this vein on the dump is largely pyrite, limonite, chalcopyrite, and quartz. A sample of the vein material contained 25 ounces of silver per ton, 11 percent copper, and a little gold, lead, and zinc. No ore was produced.

GREGORY MINE

The Gregory mine (63), in sec. 4, T. 7 N., R. 4 W., was one of the first lode deposits discovered in the area. An American Hearth reduction plant was built in 1867 and remodeled several times in later years. The mine closed in 1886 during a labor dispute (Montana Inspector of Mines, 1889, p. 106–107). According to an old tale, large blocks of ore were developed below the 400 level but not mined. In 1941 the American Smelting and Refining Co. reopened the shaft but did only a little drifting, crosscutting, and drilling, mostly from the lowest level. The company found no blocked-out ore, and the mine was closed in 1942. Incomplete records from the smelter at Wickes show that the mine produced between May 1889 and September 1890, so any ore that may have been left after the 1886 closing was probably taken out later.

The Gregory mine produced $8 million worth of ore, according to popular report (Knopf, 1913, p. 117). Production since 1902 has been a little over 4,000 tons, almost entirely from slag, mill tailings, and dumps.

The Gregory mine workings consist of a shaft 730 feet deep and drifts at depths of 257, 339, 425, 521, 618, and 720 feet. Drifts were opened in 1941 and 1942 for 400 feet to the east and west from the shaft, but drifts on all levels are caved beyond this distance and their extent is not known. Much of the vein near the shaft and above the 618 level was apparently stoped, as was some of the vein above the 720 level.

The vein strikes N. 80° W. It dips 65° N. in the upper levels and 80° N. in the lower levels. It is about 3 feet wide on the 720 level, but an old company report indicates that it ranged from 4 to 14 feet in width. Downdip, the vein goes from the Elkhorn Mountains volcanic rocks into rocks of the batholith. Volcanic rocks are on all levels down through the 521, both volcanic and batholithic rocks are on the 618 level, and mostly batholithic rocks are on the 720 level.

Vein material left on the dump from the last operation is mostly pyrite and quartz with some sphalerite, arsenopyrite, galena, and a little chalcopyrite. The mine was worked chiefly for silver and gold, but some ore mined in 1883 contained 15 percent zinc (Knopf, 1913, p. 117). Much of the ore shipped to the smelter at Wickes in 1889 and 1890 contained 0.5 to 1.0 ounce of gold and 20 to 30 ounces of silver per ton, and 10 to 30 percent lead.

MINNESOTA MINE

The Minnesota mine (61) is in sec. 5, T. 7 N., R. 4 W. It was worked mostly before 1900. Some ore was stoped from the eastern ore body above the 200 level in about 1940, and dumps have been reworked. Total production from the mine since 1900 is 700 tons of ore.

The mine consists of two shafts on the vein, drifts, crosscuts from the shafts at depths of 200 and 300 feet, and stopes that open to the surface (fig. 42). The main adit level extends about 370 feet east of the West shaft, which is flooded at the adit sill.

As indicated by the open stopes, the main vein strikes east. It dips from 80° N. to 80° S. and contains two ore bodies, reportedly of high-grade silver-lead ore. Between the ore bodies the vein pinches. The ore is partly oxidized at least down to the adit level. An altered zone 75 feet south of the main vein contains two other veins that strike N. 85° E. and dip 80° S. They are made up of stringers of quartz and tourmaline across a width of 15 inches.

The veins cut the middle unit of the Elkhorn Mountains volcanics and a small apophysis of the underlying batholith. A north-trending, probably steeply dipping, fault east of the East shaft brings postore tuff against the older rocks containing the veins and has cut off the eastward extension of the eastern ore body. According to old reports, the ore body was worked eastward to a "dike," which was actually either the fault zone or the tuff. The ore body may continue beyond the fault, but the actual direction and amount of displacement on the fault are unknown. Offset of the nearly horizontal contact between the tuff and older rocks could be accounted for by a vertical displacement of at least 200 feet, which would mean that the continuation of the ore body is at least 200 feet below the surface east of the fault, provided that there has been no horizontal displacement. With a horizontal component of movement, however, the eastern extension of the vein could be the shear zone at the Gregory mine (63) or one of several other zones of alteration south of it in the Elkhorn Mountains volcanics (pl. 1). This would mean that the rest of the Minnesota eastern ore body is below the tuff at a point where one of these zones, projected westward, is cut by the fault.

ARIADNE MINE

The Ariadne mine (62) is in sec. 5, T. 7 N., R. 4 W., about 1,000 feet north of the Minnesota mine. The workings are all inaccessible. The main adit level is a little above the bed of Clancy Creek. A shaft near the portal of the adit extends 52 feet below the adit level, and a drift extends east and west from it. Some ore was stoped near the shaft workings, according to an old company report. The veins, consisting of galena and sphalerite in a gangue of quartz, pyrite, and some tourmaline, strike east; they are reported to be 15 inches wide and high grade. They are probably cut 300 feet east of the adit portal by a quartz latite dike and cut off about 100 feet farther east by the same north-trending fault that cuts off the eastern ore body in the Minnesota mine (61).

BLUEBIRD-MOUNT WASHINGTON SHEAR ZONE

A persistent structure extends eastward through the Elkhorn Mountains volcanics from a point near the center of sec. 14, T. 7 N., R. 5 W., to the west edge of sec. 17, T. 7 N., R. 4 W. The structure is a complexly fractured, nearly vertical zone. Ore-bearing quartz veins have been mined in several places along this zone, particularly at the Bluebird-Pen Yan mine (43) and at the Mount Washington mine, which includes the Homestake shaft (46) in sec. 18 and the 1,900-foot Deer tunnel crosscut (48) in sec. 17, T. 7 N., R. 4 W.

BLUEBIRD-PEN YAN MINE

The Bluebird-Pen Yan mine (43) has been described by Knopf (1913, p. 111–114) and by Winchell and Winchell (1912). One of the older mines in the district, it has been operated intermittently since the 1870's or 1880's, and was last operated in the early 1940's. Production from the mine before 1913 is known to have totaled at least $175,000 and is thought to have been $250,000 (Knopf, 1913, p. 111). Almost 20,000 tons of ore has been produced since 1901.

The workings, which are inaccessible, include two main shafts on the Occidental Plateau and, about 350 feet below the shaft collars, a crosscut and drift about 2,200 feet long called the 600 level. According to old maps, the eastern or Bluebird shaft is connected to the crosscut level, with intervening levels at depths of about 35, 120, and 200 feet. The western or Pen Yan shaft is 215 feet deep, with levels at depths of 50, 80, 120 and 200 feet. A winze near the Bluebird shaft extends 200 feet below the 600 level, with levels at depths of 60, 135 and 190 feet.

The shear zone is in the upper unit of the Elkhorn Mountain volcanics, probably not far above the top of the batholith. From Bluebird Meadows to a point east of the Bluebird shaft the zone is intruded by a dike, probably of flb, which was called granite by Winchell and Winchell (1912, p. 288) and diorite porphyry by Knopf (1913, p. 112). The dike is preore. Ore-bearing quartz veins follow one or both walls and in places leave the dike completely and are enclosed in metamor-

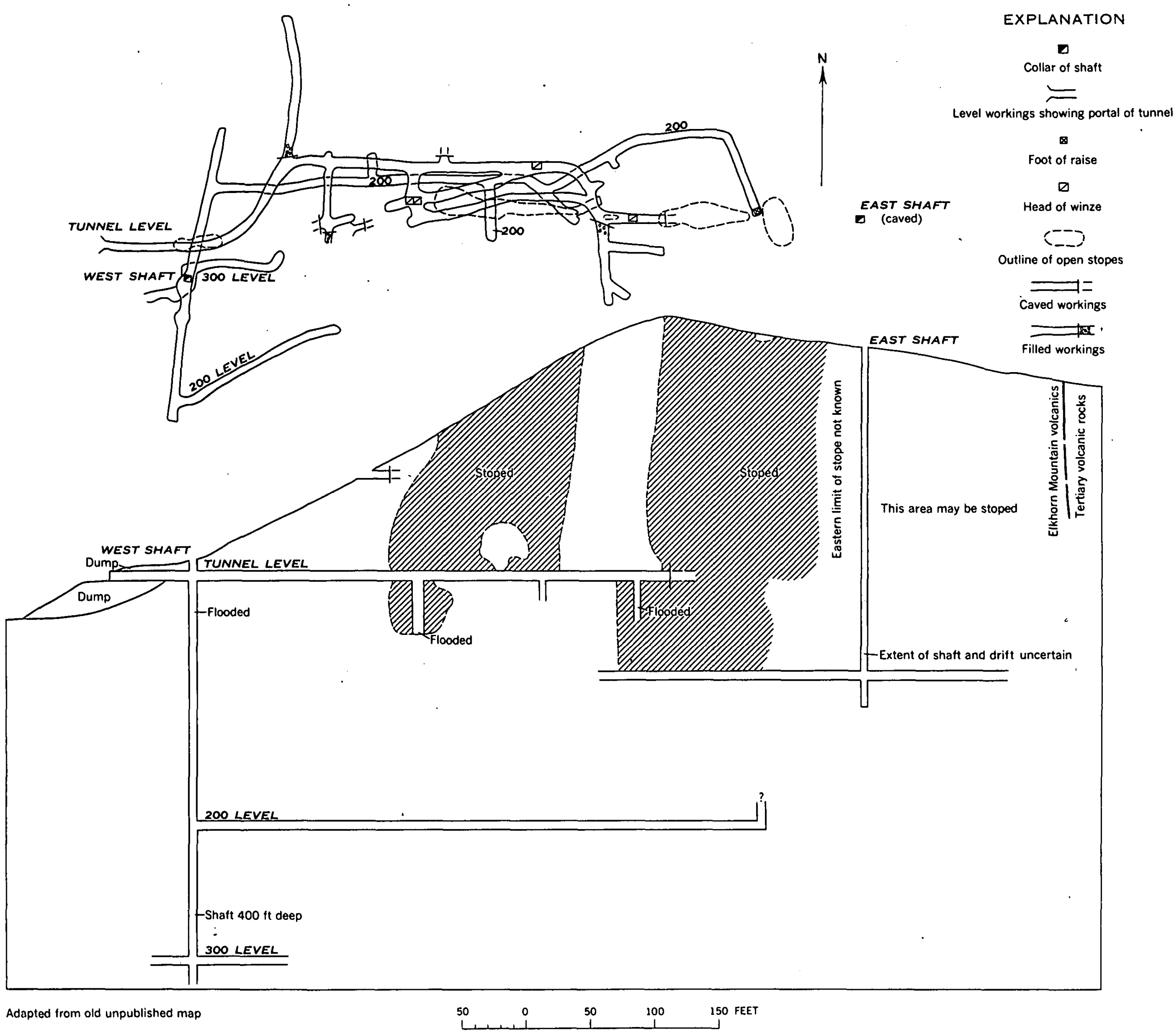


FIGURE 42.—Map and section of underground workings of the Montana mine, Jefferson County, Mont.

phosed bedded tuff ("slate" of Winchell and Winchell) of the Elkhorn Mountains volcanics. On and below the crosscut level (350 feet below the collar of the Bluebird shaft) both walls of the dike are brecciated and cemented by fine-grained tourmaline and quartz. A post-ore dike of quartz latite of Oligocene age is also intruded along the shear zone, and it contains a little pyrite locally (Knopf, 1913, p. 113).

The ore is in two bodies, one near the Blue Bird shaft and one west of it, near the Pen Yan shaft. The Pen Yan ore was valuable chiefly for gold. The Bluebird ore is mostly tourmaline, quartz, and pyrite with tetrahedrite and, locally, sphalerite, galena, arsenopyrite, and some chalcopyrite. Rhodochrosite and malachite have been reported (Winchell and Winchell, 1912, p. 288). The ore body is 40 feet wide on the 200 level of the Blue Bird shaft, where it contains many rosettes of black tourmaline crystals intergrown with pyrite. The ore contained 10–25 ounces of silver per ton and 3 to 5 percent copper (Knopf, 1913, p. 113–114); ore produced in the last 50 years averaged about 19 ounces of silver per ton and 3 percent copper.

MOUNT WASHINGTON MINE

The Mount Washington mine (46, 48), which produced about $1 million worth of ore, was discovered in 1890. By 1912 it included a shaft down to the 200 level and two large stopes. It was developed considerably between 1915 and 1919. A 50-ton mill was built prior to 1921 but was destroyed in 1923. The mine was operated by W. A. Clark, of Butte, Mont., in 1926 and 1927, and the ore was treated in the Timber Butte mill at Butte. United Gold Mines built a 150-ton mill and treated 14,000 tons of ore between January and May 1936. The greatest period of production was from 1942 to 1945, when the mine was operated by the Monongahela-Mount Washington Co. Operation ceased in 1946.

Although the mine is for the most part inaccessible, information about it has been obtained from reports and maps loaned by Mr. A. E. Nugent. The Homestake shaft (46) extends from the surface to the 800 level, and shaft No. 1 is 200 feet deep on the vein (pl. 10). The mine includes 10 working levels about 100 feet apart vertically, 3 intermediate levels above the 200 level, and many raises and crosscuts. Deer tunnel crosscut (48) is 1,900 feet long to the 800 level.

The Mount Washington vein strikes N. 80° W. It dips steeply to the north except between the 200 and 300 levels of the mine, where it dips steeply south, and below the 500 level, where it is nearly vertical. A quartz latite dike splits the vein for nearly all of its exposed length and crosses to the north side of the vein east of the Deer tunnel on the 800 level. This dike, which averages 25 feet in thickness but in places is twice as thick, probably connects at either end with two pluglike intrusive bodies of quartz latite that cut the shear zone east and west of the Homestake shaft (pl. 1). The westernmost of these two intrusive bodies probably also connects at depth with a narrower north-trending quartz latite dike. Where exposed on the 700 and 800 levels of the mine about 700 feet west of the shaft, the north-trending dike follows a strong fault zone—called the Big fault—which is 80 to 240 feet wide on the 800 level. The Big fault cuts both parts of the vein and the intervening dike, offsetting them about 240 feet to the left, and it contains some ore dragged from the vein.

The part of the vein that is north of the quartz latite dike, called the North vein, has yielded most of the ore. It is locally as much as 25 feet wide but averages about 8 feet in width, and the ore within it is reported to be from 2 to 7 feet wide. From near the Homestake shaft to a point about 500 feet farther east, the North vein contains a horsetail zone along its northern side. In this zone many small veins branch to the northeast from the main vein. Available maps show that the horsetail zone extends between the 500 and 800 levels, but above and below this interval it is not known. The South vein averages about 7 feet in width, but at the western end of the 800-level drift it is about 45 feet wide where exposed in a crosscut. Strike faults border both the North and South veins and in places cross them.

The Mount Washington ore is mostly pyrite, galena, sphalerite, and arsenopyrite, with some chalcopyrite and tetrahedrite in a gangue of primary carbonate minerals, some quartz and chalcedony. The carbonate minerals cut the sulfides. Tourmaline is rare; where it occurs it is fine grained and intergrown with quartz as in the walls of the preore dike at the Bluebird mine. The ore is completely oxidized near the surface and extensively oxidized down to the 400 level. In places, oxidized ore extends down to the 500 level. Below the 500 level the ore is primary, and sphalerite is particularly abundant.

Ore produced since 1902, including ore from dumps, averaged 0.06 ounce of gold and 7.4 ounces of silver per ton, 4 percent lead, and 0.15 percent copper; 128,000 tons of ore contained an average of 3.1 percent zinc. Ore mined from the Clark winze between the 800 and 1,000 levels averaged about 20 ounces of silver per ton, also about 6 percent zinc and slightly less lead; some contained as much as 20 percent zinc.

The Elkhorn Mountains volcanics on the dumps are intensely altered to sericite. Underground, the volcanics form strong walls, but the stopes require square-set timbering because the walls of the quartz latite dike cave easily.

MINAH MINE

The Minah mine (49) is in secs. 8 and 17, T. 7 N., R. 4 W. It has been described in detail and mapped by Lorain and Hundhausen (1948). The deposit was discovered in 1864 and was mined in the 1880's and 1890's, when a roasting and leaching plant was built but probably little used. The mine was worked intermittently for some time thereafter. Recorded production before 1903 was 29,851 tons of ore, giving a net return of $532,387 (Lorain and Hundhausen, 1948, p. 3). About 15,000 tons of ore, mostly from the dumps, has been produced since 1903. The lower tunnel was reopened in 1945 and the U.S. Bureau of Mines cut trenches on the outcrops and diamond drilled the vein in 1946 and 1947. About 1,000 tons of ore was produced in 1947 and 1948.

The mine workings include two shafts and four main levels. The East shaft is 340 feet deep from the surface to the No. 2 level; the West shaft is 300 feet deep and extends below the No. 3 level. Several raises and a winze extend from the No. 4 level. The vein is reached on the No. 4 level by a crosscut about 1,500 feet long that starts in the Lowland Creek volcanics southeast of the vein. Raises above the No. 4 level are caved, and all levels are now inaccessible.

The vein strikes nearly east. Its dip is almost vertical in the upper levels and about 65° N. near the No. 4 level. The vein is more than 2,200 feet long and contains ore for widths of 1 to 2 feet. A few smaller veins are subparallel to the main vein.

Ore minerals on the lower dumps are mostly intergrown quartz and arsenopyrite, and some pyrite, galena, and sphalerite. Tetrahedrite and chalcopyrite are also reported.

BLIZZARD MINE

The Blizzard mine (47), in secs. 17 and 18, T. 7 N., R. 4 W., is described by Knopf (1913, p. 111). It was operated from 1888 to 1896, and was last worked during and shortly after World War II. Production during the earlier period was valued at about $150,000 (Knopf, 1913, p. 111). Since 1908 the mine has proproduces 2,149 tons of ore that yielded 280 ounces of gold, 18,647 ounces of silver, 111,389 pounds of lead, and 21,375 pounds of copper; 991 tons of this ore came from the dump.

Two caved shafts and two adit crosscuts (pl. 11) are all inaccessible. They follow two veins that strike east and dip steeply. The North vein, which is stoped above the upper adit level, is a few inches to 6 feet wide and consists of thin bands of pyrite, arsenopyrite, sphalerite, galena, and some chalcopyrite, with very little quartz. The South vein contains pyrite, rhodochrosite, pyrolusite, calcite, and quartz; near the western end of the mine the vein dips 45° N. and cuts the North vein, according to Knopf. The North and South veins and a third vein, farther to the south and apparently unexplored, are exposed in the Deer tunnel crosscut (48) of the Mount Washington mine. All three veins in the crosscut contain galena, sphalerite, and pyrite.

Ore thought to be mostly from the stopes averaged 0.16 ounce of gold and 12.5 ounces of silver per ton, 3.7 percent lead, and 0.86 percent copper. Ore from the dump averaged 0.09 ounce of gold and 4.25 ounces of silver per ton, 1.4 percent lead, and 0.7 percent copper. Records of the zinc content were not kept.

ELKADOR MINE

The Elkador mine (51), in sec. 17, T. 7 N., R. 4 W., was worked before 1900 and reopened in 1940. Little is known of its history or production. The mine consists of a crosscut 340 feet long, a drift extending westward from the crosscut, and a raise on the vein to the surface (fig. 43). The drift is caved at a point 700 feet from the crosscut, and its full extent is not known. Ore was stoped near the raise, to the east near a shallow winze, and probably also in a breccia zone near the caved part of the drift.

The mine is in the upper unit of the Elkhorn Mountains volcanics and in granite porphyry of the late stage of the batholith. Neither rock type seems to be more favorable than the other for ore deposition. Near the end of the crosscut the granite porphyry contains a small alaskite body, the borders of which grade into the porphyry, and a quartz veinlet 1 inch wide in the porphyry narrows to a thin stringer in the alaskite.

The Elkador vein strikes S. 85° E. and dips 68°–80° N. It averages less than 1 foot in width but widens locally, and it tends to split into veinlets a few inches wide. At 680 feet west of the crosscut the vein occupies a breccia zone 6 to 8 feet wide and changes strike to N. 78° E. The vein material is largely coarse milky quartz and pyrite, much of it in large crystals, with a little chalcopyrite and tetrahedrite, and a few stringers of primary carbonate minerals and tourmaline. Galena and sphalerite are rare.

BONANZA, DEWEY, AND ROSALIE TUNNELS

A shattered zone 60 to 100 feet wide trends west-northwest along a gulch tributary to Clancy Creek in the NE¼ sec. 12, T. 7 N., R. 5 W., and the NW¼ sec. 7, T. 7 N., R. 4 W. (pl. 1). The zone, which cuts tuff of the Elkhorn Mountains volcanics, is intruded by a dike of late-stage batholithic rocks and is locally altered and mineralized. It was explored by means of several adits driven sometime after 1900 by the Corbin Copper Co.; a mill was built near the portal of the Bonanza tunnel (54) but never used. Production is not known. Nearly 4,000 feet of level workings extend 1,900 feet west of the portal of the Bonanza tunnel, which is about 800 feet east of the portal of the Dewey tunnel (55) and 180 feet lower. The Rosalie tunnel (56) is about 2,000 feet southeast of the Bonanza and is probably in the same shear zone. It consists of a crosscut that extends N. 12° W. for 900 feet and a drift from the crosscut to the west for 800 feet.

Where exposed at the portal of the Bonanza tunnel (54), the shear zone trends N. 75° W. and is brecciated, silicified, and oxidized. The ore minerals are galena, chalcopyrite, and sphalerite, and the ore contains masses of tourmaline and pyrite (Knopf, 1913, p. 115–116). Pyrite, quartz, primary carbonate minerals, and manganese oxide minerals are on the Dewey and Bonanza dumps (54, 55). At the Rosalie tunnel the ore is similar and of good grade, but the quantity is small.

BLACKBIRD GROUP

The Blackbird group (53) is in sec. 12, T. 7 N., R. 5 W., and sec. 7, T. 7 N., R. 4 W. The veins were discovered in the 1880's. They were trenched and explored underground during World War II. Very little production is reported, and most of the workings are inaccessible. No. 1 tunnel (alt. 6,804 ft.) is a crosscut extending 210 feet to the north; from it, a drift extends

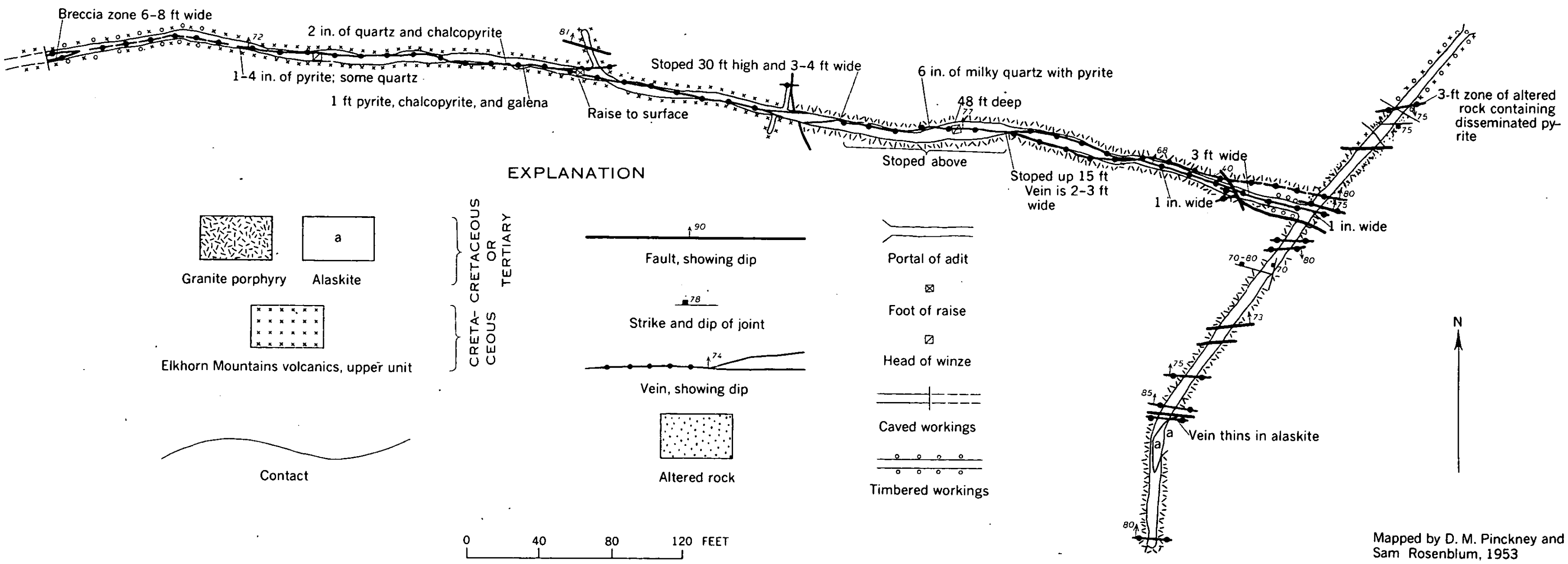


FIGURE 43.—Geologic map of the Elkador mine, Jefferson County, Mont.

55 feet east and 70 feet west. No. 2 and No. 3 tunnels (Badger tunnel) explore the southernmost of two parallel veins that are about 100 feet apart. A caved adit and a shaft reach the westernmost crosscut at an altitude of 7,000 feet (Carl Tolman, written communication).

The veins, in Elkhorn Mountains volcanics, strike east and dip 35°–70° N. They contain manganese oxide minerals, including pyrolusite and psilomelane, and iron oxides. The south vein contains two ore bodies of restricted extent. The eastern body is 14 feet wide in surface cuts and 6 to 8 feet wide in the Badger tunnel; it pinches to small stringers in the drift east from the No. 1 tunnel crosscut (Carl Tolman, written communication). A shipment of ore from the eastern body contained about 20 percent manganese and 15 percent iron. The western body (alt. 7,000 ft.) dips 45° N.; it is 6 feet wide at the collar of the shaft but 2 feet wide and lower grade in a drift 40 feet lower.

The north vein, north of the eastern body of the south vein, dips 70° N. at the surface and contains a low-grade ore body 6 feet wide. It is not found in the No. 1 crosscut.

GENERAL HARRIS PROSPECT

On a ridge in sec. 8, T. 7 N., R. 4 W., about a mile east of the Blackbird group, a fractured, mineralized zone about 75 feet wide is exposed in the shallow trenches of the General Harris prospect (49). Quartz stringers and veins as much as 1½ feet wide strike N. 70° E. and dip 85° N. They contain manganese and iron oxide minerals as at the Blackbird mine and would probably assay about 15 to 20 percent of both manganese and iron (M. R. Klepper, written communication). The stringers and veins are separated by 1 to 5 feet of Elkhorn Mountains volcanics seamed with fractures; the fractures also contain manganese and iron oxide minerals.

SALVAIL MINE

The Salvail mine (45) is in sec. 19, T. 7 N., R. 4 W., in Wood Chute Gulch. It has been described by Pardee and Schrader (1933, p. 237–238). The deposit was found in 1903 and was worked in the late 1920's. Several carloads of ore shipped in 1928 contained 0.31 to 0.40 ounce of gold per ton, 14 to 28 ounces of silver per ton, and 2.0 to 3.4 percent copper.

A crosscut adit extends to the north 1,200 feet and intersects two veins that strike eastward, a North vein 800 feet from the portal and a South vein 250 feet from the portal. A drift on the North vein is 800 feet long (Pardee and Schrader, 1933, pl. 39). The adit is now caved at the South vein. The North vein dips 74° N., averages 5 feet in width, and contains ore bodies up to 3 feet wide consisting of chalcocite, chalcopyrite, galena, sphalerite, pyrite, arsenopyrite, ruby silver, bournonite, and quartz. The North vein is offset 60 feet by a northeast-trending fault. The South vein is a sheared zone 64 feet wide that dips 75° N. It contains some low-grade ore.

DAILY OR ATLAS MINE

The Daily or Atlas Mine (70) is in sec. 16, T. 7 N., R. 4 W., a few hundred feet west of the site of the old smelter at Wickes. It was worked before 1879, but the period of greatest development and production was probably between 1900 and 1905. According to estimates given in old company reports, about $50,000 worth of ore was produced before 1900. Production since 1902 has been 1,081 tons of ore that yielded 76 ounces of gold, 31,847 ounces of silver, 100,668 pounds of copper, and 4,800 pounds of lead. In 1956 the Uranium Corp. of America purchased the mine and reopened most of the workings. Plans were made to extend the drifts to the east and west on the lowest level and to deepen the shaft.

The mine consists of a vertical shaft 340 feet deep, levels at depths of 100, 200, and 300 feet, and stopes of unknown extent above the 100 and 200 levels, and probably also above the 300 level. All these workings are on the Atlas vein. A crosscut on the 300 level extends 310 feet north from the Atlas vein to the Steamboat vein (pl. 12).

The Atlas vein strikes N. 75°–90° E. on the 200 level and east on the 300 level, and it dips 70°–80° S. It occupies an intensely fractured and altered zone 5 to 20 feet wide in the roof remnant near the top of the batholith. The rock is fractured in most places into lenses an inch or two wide and a few inches long. What little gouge is present is mostly along a strong, persistent fracture in the footwall of the vein. Where exposed in the timbered drifts on the 200 and 300 levels, the vein has an average width of 5 feet and locally is more than 8 feet wide. It is a layered vein and contains much altered wallrock in which sulfide minerals are disseminated. In several places the hanging wall contains thin veinlets that strike about N. 65° E. and intersect the more eastward striking Atlas vein. Near and to the east of these intersections, the Atlas vein is wider and contains less wallrock; raises have been put up and probably some stoping done; this work suggests that the vein is also higher grade near the intersections than elsewhere.

The Steamboat vein is known only on the 300 level in a short drift reached by a crosscut from the Atlas level. It strikes N. 80° E. and dips 75°–85° S. Near the crosscut the vein consists of a few narrow stringers, but it widens to 18 inches at the eastern face of the drift. West of the crosscut, the vein apparently widens rapidly, for the drift westward is caved and filled by blocks of vein material as much as 4 feet wide. The Steamboat vein is largely white to gray quartz in intensely brecciated, altered, and replaced volcanic rocks. Pyrite is abundant. The vein contains some galena, sphalerite, and chalcopyrite, and a little tetrahedrite.

Three broken, altered, and mineralized zones are exposed in the crosscut between the Atlas and Steamboat veins. These zones range from 10 to 35 feet in width, strike about N. 60° E., and probably dip about 60° N. All contain small veins and stringers of pyrite and chalcopyrite with quartz, and the ratio of chalcopyrite to pyrite seems to be larger than in either the Atlas or the Steamboat vein. If these zones persist along strike, the northernmost one would intersect the Steamboat vein about 110 feet east of the crosscut, and the southernmost one would intersect the Atlas vein about 140 feet west of the crosscut.

DAVID COPPERFIELD ADIT

On the southern end of Alta Mountain in secs. 15 and 16, T. 7 N., R. 4 W., rocks of the batholith and the roof pendant are intensely fractured and altered for a distance of about 2,000 feet north of the railroad tracks. Rock in the railroad cuts is largely altered to sericite and contains pyrite and quartz scattered through it. The David Copperfield adit (69), now caved, was driven northward from a point below the railroad tracks and may go under an irregular siliceous gossan nearby. The large dump of the adit contains mostly rock like that in the cut above it, except that the amount of quartz and pyrite is much greater on the dump. Rocks at the surface in this area are intensely iron stained.

BERTHA MINE

The Bertha mine (66), in sec. 3, T. 7 N., R. 4 W., three-fourths of a mile northeast of the Alta mine (67), was discovered in the early period of mining. A mill was operated at the mine during part of its main period of activity, which was from 1907 to about 1918. The mine produced a little less than 90,000 tons of ore, mostly between 1912 and 1918.

All the workings are caved at the surface, and information about them is from old maps and reports. An upper shaft on the vein north of the creek is 195 feet deep, with a main drift extending about 400 feet southwestward and 460 feet northeastward to the surface (adit No. 2) and three small stopes above the drift. The Bertha shaft, south of the creek, is 900 feet deep with levels called the 300, 500, 600, 700 and 1,200 (measured from the upper shaft, which is 300 ft. above the Bertha shaft). The 300 and 500 levels extend 1,500 feet to the southwest, and the 300 level opens to the surface along the creek southeast of the Bertha shaft. Crosscuts on the 700 and 1,200 levels extend northwestward of the shaft for 600 and 850 feet respectively. Only the 600 level extends northeast of the shaft, and it extends only 130 feet in this direction. Although some of the drifts extend southwestward about 500 feet under the Elkhorn Mountains volcanics, only batholithic rocks are on the dumps.

The vein strikes N. 40° E. and dips 80° S. Its width ranges from a few inches to 10 feet, averaging 4 feet on the 700 level but somewhat less on the 900 and 1,200 levels as well as on the upper levels. Milky to gray quartz and coarse crystalline pyrite are abundant. The vein contains 2 to 3 percent copper and a little silver and gold, mostly in chalcopyrite and minor tetrahedrite (Knopf, 1913, p. 110). Cosalite and bornite are also reported in the ore. Near the upper shaft the vein is oxidized to depths of from 40 to 100 feet. The structure extends at least 1,500 feet northeast of the Bertha shaft to another shaft, where it is an altered zone 10 feet wide containing veinlets a few inches wide.

An old caved shaft about 500 feet east of the upper shaft of the Bertha mine is on a partly oxidized vein containing quartz, pyrite, galena, and sphalerite. This vein is probably parallel to the Bertha vein. A sample of fresh sulfide ore from the dump contained about 13 ounces of silver per ton, 17 percent lead and 26 percent zinc, but very little copper.

A third vein, also parallel to the Bertha vein, is explored by a shaft about 450 feet northwest of the upper shaft. A few feet wide, the vein contains mostly quartz and pyrite, some chalcopyrite and tetrahedrite, and a little galena and sphalerite. Samples from the dump contain about 10 ounces of silver per ton, 6 percent copper, and about 1 percent each of lead and zinc.

MONTE CHRISTO ADITS

The two Monte Christo adits (64) are in sec. 3, T. 7 N., R. 4 W. The upper (No. 2) adit follows a vein that strikes east and is vertical or nearly so (fig. 44), and consists of short lenses and stringers of quartz and sulfide minerals. The vein averages about 10 inches in width, but in places is as wide as 7 feet. A drift from the No. 1 adit follows a similar steeply dipping quartz vein that strikes east-southeast and is 3 to 4 feet wide. Both veins are in Butte quartz monzonite. A quartz latite dike has intruded the quartz monzonite along the southern side of the vein in the No. 1 adit drift and cuts off the vein 190 feet east of a winze (fig. 44). In a short crosscut that extends southward from the drift, the dike and vein are separated by a narrow band of intensely sericitized quartz monzonite. The dike is not altered to sericite and is therefore considered to be younger than the vein and its accompanying alteration.

LONE EAGLE MINE

The Lone Eagle mine (42), on the South Fork of Quartz Creek in sec. 31, T. 8 N., R. 4 W., is an old prospect that was reopened in 1952 and explored for uranium. A small quantity of uranium ore was produced from a uranium-bearing quartz-chalcedony vein that strikes about N. 45° E. and dips 50°–75° SE. The vein, which ranges in width from 1 to 5 feet, is reached by a crosscut 275 feet long and explored by a drift 360 feet

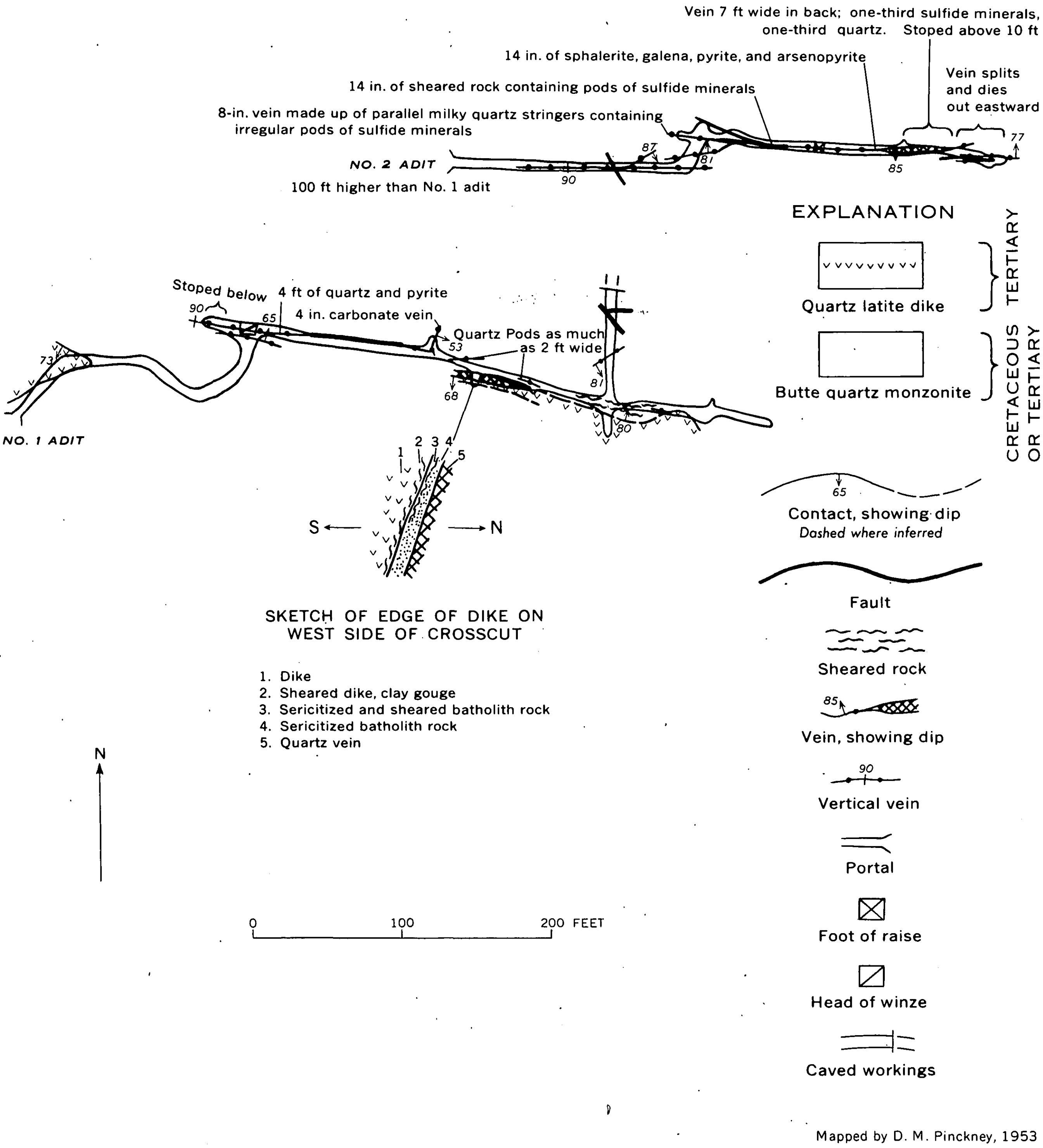


FIGURE 44.—Geologic map of the Monte Christo adits, Jefferson County, Mont.

long (fig. 45). It is offset a few feet to the right by faults that strike east or northwest and dip steeply. Northeast of the crosscut, the uranium-bearing vein splits into two parts.

The vein consists mostly of quartz and chalcedony or microcrystalline quartz; it also contains pyrite, sphalerite, galena, and minor argentite. Pitchblende is associated with microcrystalline quartz, and both min-

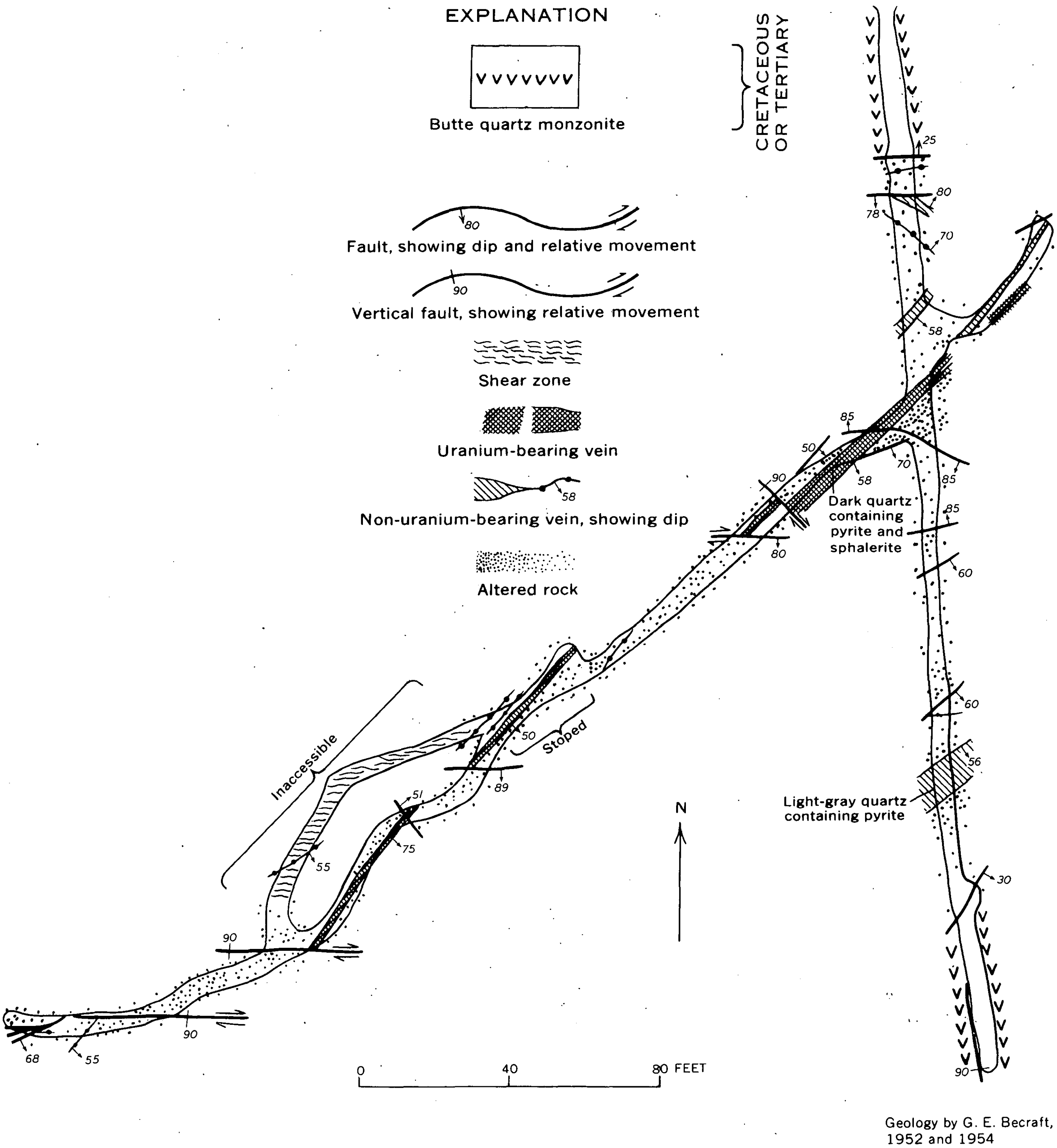


FIGURE 45.—Geologic map of the Lone Eagle mine, Jefferson County, Mont.

erals were deposited after the coarse quartz and most of the sulfide minerals (Wright and Shulhof, 1957, p. 127–128; Wright and others, 1957).

A quartz vein 10 feet wide containing pyrite but no uranium strikes N. 55° E. and dips 56° S. in the crosscut about 100 feet south of the uranium-bearing vein. It has not been explored.

GOLCONDA MINE

The Golconda mine (76), in sec. 29, T. 7 N., R. 3 W., includes three adits and is said to total 3,000 feet of workings. The middle and upper adits were open in 1954. Production valued as high as $100,000 is reported by Reyner and Trauerman (1942, p. 39).

The mine is in a mineralized fault breccia cemented with sulfide minerals and bounded by strong gouge strands. Sphalerite is the dominant ore mineral in the breccia zone. Galena, pyrite, and sparse arsenopyrite, in a gangue of quartz, are also present. In the middle adit (fig. 46), the hanging wall of the breccia contains many small irregular fractures that are also mineralized, and alteration has pervaded the hanging wall along these fractures. Pits on the surface open similar areas of fractured rock cut by many thin veinlets of limonite.

OTHER MINES

Bluestone mine (44)

Location.—Sec. 18, T. 7 N., R. 4 W., on Wood Chute Creek.

Reference.—Pardee and Schrader (1933, p. 238).

Mine Workings.—Two crosscuts and a shaft, caved.

Vein.—Strike, northwest; dip, 50° N. Averages 2 feet in width in upper workings, 4 inches in lower tunnel. Oxidized near shaft.

Wallrock.—Elkhorn Mountains volcanics.

Mineralogy.—Arsenopyrite, pyrite, galena, sphalerite, and chalcopyrite in lower tunnel.

Montana tunnels (52)

Location.—Sec. 8, T. 7 N., R. 4 W.

History.—Operated about 1900 by the Corbin Copper Co.

Mine workings.—Two caved adits connected by a winze 35 feet deep. Size of dumps indicates at most only a few hundred feet of underground workings.

Ore body.—A mineralized tuffaceous conglomerate or breccia pipe. (See p. 51.) Oxidized near surface.

Mineralogy.—Sphalerite, a little galena and ruby silver (?), pyrite, coarsely crystalline comb quartz, and microcrystalline or chalcedonic quartz.

Grade.—About 8 ounces of silver per ton over a length of 130 feet in the upper tunnel (Knopf, 1913, p. 116).

Dow crosscut (57)

Location.—Sec. 7, T. 7 N., R. 4 W.

Mine workings.—Crosscut extending 1,200 feet southward from southern side of Clancy Creek.

Veins.—Strike, east. One 2 feet wide near end of crosscut; another nearer the portal.

Tenor.—The 2-foot vein contains about 7 ounces of silver per ton, 12 percent lead, and 2.5 percent copper.

Glenberg mine (58)

Location.—Sec. 7, T. 7 N., R. 4 W.

History and production.—More than 500 tons of ore mined between 1909 and 1919.

Mine workings.—Crosscut extending 725 feet southward from southern side of Clancy Creek.

Tenor.—About 25 ounces of silver per ton, 4½ percent copper, 7 percent lead, a little gold.

Rarus mine (65)

Location.—Sec. 2, T. 7 N., R. 4 W.

Production.—A few thousand tons, estimated.

Mine workings.—Adit drift on vein, about 300 feet long, flooded winze below and small stope above.

Vein.—Strike, N. 75°–85° E.; dip, about 65° N. Overlapping lenses up to 5 feet wide and about 100 feet long, separated by 15 to 25 feet of altered Butte quartz monzonite. Ore body in stope near winze plunges about 15° E.

Mineralogy.—Outcrops contain milky quartz and chalcedony, some siliceous boxworks, limonite, and barite. Vein in drift mostly milky quartz; pyrite, galena, sphalerite, and some chalcopyrite and tetrahedrite in ore body; minor barite. Stringers of chalcedony cut milky quartz.

Polaris mine (72)

Location.—Sec. 11, T. 7 N., R. 4 W.

Mine workings.—Two adits at about the same altitude and 300 feet apart.

Vein.—Two narrow branching veins in southeastern adit separated by a zone 45 feet wide containing quartz stringers. Strike, northeast. Dip, steep.

Mineralogy.—Mostly gray to white quartz and pyrite; some galena, sphalerite, and chalcopyrite. Thin seams of molybdenite in some quartz on dump.

Helena Jefferson mine (73)

Location.—Sec. 13, T. 7 N., R. 4 W.

Reference.—Pardee and Schrader (1933, p. 238–240).

History.—Worked in the late 1920's. Main adit reopened and some prospecting in 1955.

Mine workings.—Inclined shaft 550 feet deep; main adit crosscut to drift about 100 feet below shaft collar on Helena vein; prospect adits and pits on other veins.

Helena vein.—Strikes N. 45° E., dips 50°–60° N. (not northwest strike and northeast dip of Pardee and

Schrader). Pyrite, galena, sphalerite, some quartz; molybdenite on joints in quartz monzonite.

New York vein.—1,250 feet west of shaft on Helena vein; dip 75° N.; band of manganese oxide minerals 6 inches wide in fractured zone; manganiferous gossan 5 feet wide on vein; rhodochrosite, rhodonite, and alabandite reported.

Other veins.—Four more reported by owner. Strike, northeast.

Reddings or Silver Tip mine (74)

Location.—Sec. 8, T. 7 N., R. 3 W.

Reference.—Pardee and Schrader (1933, p. 240).

Production.—About $10,000 worth of ore that contained about 70 ounces of silver per ton, 17 percent lead, 2 percent zinc.

Mine workings.—Three adits.

Vein.—Vein is in easternmost of two lower adits; strikes N. 45° E.; dips 45° N.; and is 1 to 2 feet wide. In winze below adit level, vein is in brecciated batholithic rock; contains partly oxidized and leached sphalerite, pyrite and galena. Manganese oxide stain abundant elsewhere along vein.

Big Chief mine (75)

Location.—Sec. 17, T. 7 N., R. 3 W.

Mine workings.—Shaft; adits at 3 levels on vein, lower 2 adits connected by 21-foot raise.

Vein.—Strike, N. 75° E.; dip, steep to vertical; 1 to 2 feet wide. In broken and altered zone up to 40 feet in width containing gouge strands, disseminated pyrite.

Mineralogy.—Black sphalerite, galena, pyrite, and a

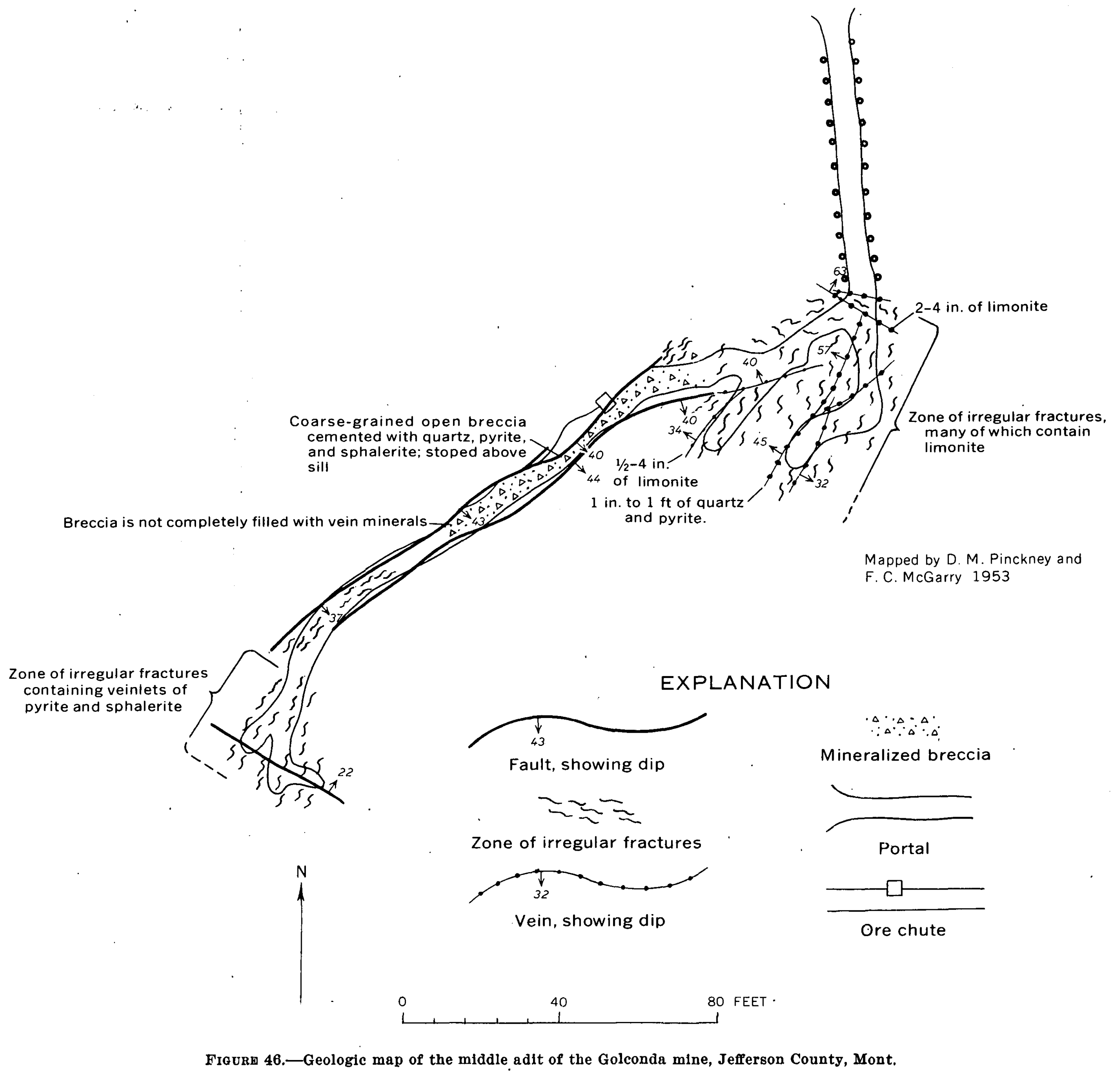


FIGURE 46.—Geologic map of the middle adit of the Golconda mine, Jefferson County, Mont.

little chalcopyrite in stringers and bands in central part of altered zone. Brecciated sulfide minerals cemented with milky quartz and primary carbonate minerals.

CATARACT CREEK, BOULDER, AND AMAZON DISTRICTS

The southern part and most of the western part of the quadrangle is included within the Cataract Creek, Boulder, and Amazon districts. Because these districts are not geographic or geologic units and because some of the mines in them have been included in different districts by different authors, the three are treated together in this report. Access in the area is provided by the Great Northern Railroad, U.S. Highway 91, and several good graded gravel roads.

The rocks in the district are largely Butte quartz monzonite, but they also include Elkhorn Mountains volcanics, alaskite, and quartz latite. In many places they are deeply weathered. Both quartz veins and chalcedony veins are present in the districts, as well as a few mixed veins. Many of the chalcedony veins are concentrated in a few square miles between the Boulder Valley and Boomerang Gulch, in places so closely spaced that the smaller ones could not be shown on the geologic map (pl. 1). A small amount of uranium ore has been produced from the chalcedony vein at the Free Enterprise mine (90). Most of the quartz veins are along or near the long, complex Comet-Gray Eagle shear zone or in the Cataract Creek area in the western part of the quadrangle. Of all the mines in the Boulder batholith outside of Butte, the Comet mine (100) is second only to the Alta mine as a producer of metals.

COMET-GRAY EAGLE SHEAR ZONE

The Comet-Gray Eagle shear zone is the strongest and most persistent structure known in the quadrangle. A complex zone that trends N. 80° W. and dips very steeply, it extends eastward about 8 miles from near the Morning Glory mine (98) on Cataract Creek to the area north of the Boulder Valley, and it ranges in width from about 50 to 500 feet. The volcanic rocks of the roof remnant and the underlying rocks of the batholith are all cut by the shear zone. The shear zone in turn is cut by northward-trending quartz latite dikes, which are exposed in mine workings and diamond-drill holes. Much of the rock along the entire length of the zone has been altered, and, in places, extensively mineralized.

North of the Boulder Valley, the eastern end of the zone swings to the northeast and splits into strands which die out in about 1½ miles. Westward, the exact location of the zone is not known because the eastern side of the valley of Cataract Creek is heavily timbered and covered in most places, but the presence of the zone is indicated by topography, altered rock from prospect pits, and one small vein. The main part of the zone probably passes through or south of the broad-bottomed gulch about 1,300 feet north of the Morning Glory mine (98). No indication of the zone has been found west of Cataract Creek, indicating that it probably terminates at its juncture with the lineament that determined the course of the creek.

A very similar sheared, altered, and locally mineralized zone splits from the main zone near the head of Boomerang Gulch about one-third of a mile east of the Comet mine (100). This zone, referred to as the Bismark-Van Armin zone, trends northeastward where it splits from the main shear zone, but farther to the northeast it swings more to the east. It is traceable for about 2 miles and seems to die out to the east.

Another interpretation of the structure is that the main strand of the Comet-Gray Eagle shear zone swings to the northeast at the head of Boomerang Gulch, continues eastward through the Bismark-Van Armin zone and dies out. A different major structural zone may be represented by the veins and altered zones extending a little south of west from the northwest corner of sec. 2, T. 6 N., R. 4 W., passing through the Mono (107) and Pilot (93) mines, to the north edge of sec. 7. The zone of sheared and altered rock extending from the head of Boomerang Gulch eastward to the east-central edge of sec. 5, T. 6 N., R. 4 W. may be a connecting link between two major structures.

Most of the rocks in the Comet-Gray Eagle shear zone have been altered to sericite and clay minerals, and, in places, a considerable amount of pyrite is disseminated through the rock. Veins at different places along the shear zone range from tiny seams to large veins as much as 100 feet wide and half a mile long. Quartz is the most widespread and abundant mineral in the veins, but they also contain varying amounts of pyrite, galena, sphalerite, arsenopyrite, chalcopyrite, uranium minerals, and carbonate gangue minerals. Sulfide ore bodies large enough and rich enough to encourage mining were found on the surface at about 10 places along the shear zone and its northeastern split. The ore bodies have been mined for their silver or silver-lead content.

Primary carbonate minerals are much more abundant near the ends of the Comet-Gray Eagle shear zone than along its middle part. Between the Great Northern Railway tracks and the head of Boomerang Creek minerals of the primary carbonate assemblage are sparse. East of the railroad tracks carbonate minerals are more abundant, especially at the Mono group of mines (107, 108). Along the zone westward from Boomerang Creek, the primary carbonate minerals occur locally in the Comet mine (100); they are abundant in one or more veins in the Gray Eagle mine (99); and they are very abundant at the Morning Glory mine (98) on the extreme western end of the shear zone.

Radioactivity has been detected on the dumps of several mines along the shear zone, but traverses along the entire length of the zone failed to disclose any radioactivity anomalies along the trace of the outcrop at the surface. This may be due to thick cover and thorough leaching of uranium from the zone near the surface.

COMET MINE[4]

The Comet mine (100) is near the head of High Ore Creek in sec. 36, T. 7 N., R. 5 W., about 1½ miles east of the Gray Eagle mine. The ore body was discovered in 1874. The Helena and Livingston Smelting and Reduction Co., organized in 1883 primarily to operate the Alta mine (67), operated the Comet mine, hauling ore by a rope tramway from the mine to their smelter at Wickes. By 1889 the mine had been developed by a three-compartment shaft 500 feet deep (Montana Inspector of Mines, 1889, p. 105), and during this period a mill was built on High Ore Creek. The mill apparently was poorly suited to treating the Comet ores, and the tailings from it were later reworked. Company reports state that the old tailings yielded metal worth $1,400,000. The mine apparently continued production through and after the silver panic of 1893, but in 1897 it was closed. One of the chief expenses at this time was the cost of the great amount of firewood required to operate the pumps that kept the mine pumped out.

The mine was owned by the Montana Consolidated Copper Co. from shortly after 1900 until the Basin Montana Tunnel Co. purchased it in 1927. During this period a new shaft, called the Comet shaft, was sunk to a depth of 975 feet, and levels were driven at 100-foot intervals down to the 800 level. The mine was worked by several different operators, and although quite a bit of drifting and raising was done above the 400 level, the veins were not systematically explored. Most of the ore above the 100 level and much above the 200 level was taken out, but very little stoping was done between the 300 and 400 levels. No mill was available nearby in which the lower grade material could be treated.

In 1931 the operation was taken over by the Basin Montana Tunnel Co. and a systematic exploration and development program was started. The mine was reopened through the Comet shaft, and a selective flotation mill with a capacity of 200 tons per day was built at Comet to treat ores from both the Comet mine and the Gray Eagle mine (99). By 1934 the Comet had been sufficiently developed so that nearly 60,000 tons of ore was produced in that year. From 1934 through 1940 production averaged about 58,000 tons a year. In 1941 the known ore bodies were considered to be worked out and both mines were closed.

The early production is not accurately known, but the production to 1911 was popularly reported to be about $13 million (Knopf, 1913, p. 114–115). The total value of silver, lead, zinc, gold, and copper produced from the mine is reported to have exceeded $20 million.

Total recorded production for the Comet mine from 1904 to 1950 is 493,444 tons of ore, which yielded 41,754 ounces of gold, 3,152,896 ounces of silver, 28,222,300 pounds of lead, 23,835,847 pounds of zinc, and 2,234,353 pounds of copper. Because at different times the mine has been worked in conjunction with other mines, some ore not from the Comet mine is included with the above figures. The Gray Eagle mine has contributed the most, but some also has come from the Silver Hill claim, adjacent to the Comet on the west, and from the Bullion and Crystal mines in the Basin quadrangle to the west.

In addition to the production recorded above, ore-purchase records from the smelter at Wickes for the period July 11, 1889, to June 25, 1893, show that at least 3,295 tons of ore was received from the Comet mine. Also shipped to Wickes during this period were 312 cars of ore for which no weight is recorded.

Three main veins and many smaller veins are exposed in the mine workings (pl. 13). The three main veins occupy a fractured, altered, and mineralized zone about 150 feet wide on the 100-foot level. Below this the veins diverge slightly so that the zone is 350 to 400 feet wide on the 300-foot level and below. Within this zone the veins strike west to N. 70° W. and dip steeply south to vertically. The north vein dips steeply north in fault blocks between the 300 and 400 foot levels, but below this it dips steeply south. The three main veins range from narrow seams to wide mineralized zones containing two or more wide veins and totaling as much as 95 feet in width.

East of the shaft on all levels above the 800 level, the veins are cut by a quartz latite dike that strikes about N. 20° E. and dips about 57° W. This dike crosses to the west of the shaft a little below the 800-foot level. Near the eastern end of the workings on the 300-foot level, another quartz latite dike strikes N. 20° E., but dips 73° E.

The veins narrow along strike and in places terminate as thin stringers or are offset by cross faults, beyond which they are weaker or have not been found. As well as can be determined from company maps, the

[4] Most of the following material is from many reports and maps of the Basin Montana Tunnel Co., loaned by Mr. R. H. Mills of Spokane, Wash.

walls of the veins in many places are gradational across a zone of altered wallrock containing many veinlets. The veins also contain many thin horses of altered and mineralized wallrock, but these are thought to be of limited extent and to constitute only a small part of the veins. In mining, most of these horses were broken with the ore and the larger pieces were left in the stopes.

The north vein is the most continuous of the three main veins. On a horizontal plane it is generally lenticular, and it is widest near the shaft. On the 300-foot level the vein is about 40 feet wide west of the shaft and has been exposed nearly continuously along a strike length of about 2,100 feet. To the east on the 300-, 400-, 500-, and 600-foot levels the vein narrows and probably pinches out, but the sheared and altered zone continues. To the west on some levels the vein narrows and terminates either in a blunt end or against a cross fault. The widest part of the vein is only about 20 feet wide on the 100 level. It widens to 25 to 40 feet in different places between the 300- and 600-foot levels and below this it again widens, so that on the 700 level it is 70 feet wide, and a smaller vein 25 feet wide is separated from it by a fault and a few feet of wallrock.

The middle one of the three main veins strikes nearly west, dips steeply south, and ranges from a thin stringer to a zone as much as 50 feet wide. Its average width is about 10 feet. This vein joins the north vein between the 200- and 400-foot levels and converges down dip with the south vein.

The south vein strikes N. 75° W. to west and dips nearly vertically. It is somewhat less continuous along strike than the north vein and seems to consist of one main vein along or near which are at least two wide lenses of vein material. Several branches a few feet wide or less diverge from these wide bodies along strike, especially on the 400-foot level. A similar wide body along the south vein crops out at the discovery site on a ridge about 700 feet S. 60° E. from the shaft. An old caved stope on the surface here is about 30 feet wide and 230 feet long. The best information available indicates that this body was not explored below the 100-foot level.

Ore bodies.—Each of the three major veins contained at least one ore body that extended from the surface to a depth of 400 to 600 feet. Above the 100-foot level the ore was partly oxidized, but little oxidation extended as deep as the 200-foot level. The maximum length of any one ore body was about 600 feet, and the widths ranged from less than a foot to 25 feet. The north and south veins contained large overlapping ore bodies on different strands of the same vein and several smaller ones scattered along the veins. The middle vein contained one ore body that was mined nearly continuously from the 400-foot level to the surface.

A few of the smaller ore bodies pinch out, and in general all the ore bodies become low grade toward their margins. The veins do not appreciably narrow near the edges of ore bodies, but the amount of ore minerals decreases and the amount of gangue minerals increases. The large ore bodies bottomed between the 400- and 600-foot levels.

The ore consisted of galena, sphalerite, and pyrite, and some arsenopyrite, chalcopyrite, and tetrahedrite, in a gangue of quartz, carbonate minerals, and altered wallrock. Most of the quartz is coarsely crystalline and milky, but in places it is gray and very fine grained. Away from the ore bodies, the veins are almost entirely quartz that contains abundant pyrite and small amounts of galena and sphalerite. Radioactive material was found at two places on the dump, and selected specimens of this material contained as much as 0.52 percent uranium.[5] No uranium minerals were identified.

Tenor.—The tenor of all ore and tailings credited to the Comet mine by U.S. Bureau of Mines production data from 1901 to 1950 (including some ore from other mines) is 0.084 ounce of gold and 6.4 ounces of silver to the ton, 3.2 percent lead, 3.9 percent zinc, and 2.2 percent copper. The tenor of the ore produced by the Basin Montana Tunnel Co. was 0.084 ounce of gold and 6.4 ounces of silver to the ton, 11.8 percent lead, 7.3 percent zinc, and 0.9 percent copper. Some of the oxidized ore mined in the early period of activity and thought to be average contained about 0.24 ounce of gold and 16 ounces of silver to the ton, and about 15 percent lead. Much of the sulfide ore shipped in the early days to the smelter at Wickes contained approximately 0.25 ounce of gold and 28 ounces of silver to the ton, 24 percent lead, 10 percent zinc, and 12 percent iron.

Although the amounts of gold, silver, lead, and zinc in the veins gradually decreased and the amount of silica correspondingly increased with depth as the large ore shoots bottomed, the copper and iron content were about the same on all levels. The average copper content of the veins (as opposed to just the ore bodies) on all levels was about 0.25 percent, and iron averaged about 12 percent.[6]

SILVER HILL MINE

The Silver Hill mine (106) adjoins the Comet mine on the west. It is developed by a shaft 165 feet deep from which several levels have been driven. The mine is inaccessible, but available mine maps indicate that the northern crosscut on the 65-level intersects exten-

[5] Alice Caemmerer, analyst.

[6] According to averages prepared by B. W. Stewart, company geologist, and based on 1,500 samples.

sions of the three main veins that were mined in the Comet mine; where the veins were intersected, they contained only small amounts of sulfide minerals.

Moderate radioactivity was detected on the dump. The radioactive material, which occurs along joints and fractures in the vein material, was not identified.

GRAY EAGLE MINE[7]

The Gray Eagle mine (99) is in sec 35, T. 7 N., R. 5 W., about 1½ miles west of Comet. The deposit was discovered in 1891 and was actively worked until about 1906. During most of the years between 1906 and 1928 the mine was worked by lessees. In 1928 the Basin Montana Tunnel Co. reopened the mine and successfully explored the veins to the east. Ore was treated in the Comet mill until 1937, when the known ore bodies were considered to be mined out.

In 1951 geologists of the U.S. Atomic Energy Commission found radioactivity on the dump. The Commission did some exploratory work but did not pump out the mine.

Production.—The Gray Eagle ore was mined chiefly for its silver content. It also yielded considerable lead and zinc and a little copper, but only a small amount of zinc was recovered until the ore was sent to the Comet mill. The value of all metals produced is estmiated to be about $1 million (Becraft, 1956, p. 358).

During the years 1901–32, 1943, and 1950, the mine produced a recorded total of 16,350 tons of ore that yielded 1,374 ounces of gold, 363,840 ounces of silver, 4,338,022 pounds of lead, 238,683 pounds of zinc, and 87,255 pounds of copper. From 1932 to 1942 the Gray Eagle production was reported with the Comet mine production. Production before 1901 is not known, but probably a considerable quantity of ore, mostly oxidized, was taken from the upper part of the western ore body during this period. Almost all of the ore mined above the 400 level was taken out before 1907.

Mine workings.—The mine is developed by 6 main levels, 2 winzes from the 400 level to the 600 level, and 1 underground shaft (called the New shaft) from the 400 to the 700 levels (pl. 14). The 400 level, about 50 feet above the creek bottom, is the main haulage level; almost all of the ore above it was mined before 1907. In 1951 the Atomic Energy Commission drove a crosscut at the 400 level and connected with one of the winzes, for the purpose of examining the mine.

Veins.—The Gray Eagle vein system lies within and parallel to the Comet-Gray Eagle shear zone. The system is composed of two main veins about 100 feet apart and many smaller veins within a wide altered zone (pl. 14). Both main veins strike about N. 75° W. The north vein, which is the larger, is nearly vertical and is as much as 40 feet wide; the south vein dips about 85° N. and ranges from a thin seam to about 2 feet in width.

The north vein is a zone composed of many bands of vein material and mineralized rock, most of which are nearly parallel. In several places individual veins strike more to the east than the overall trend of the vein zone and form a low-angle en echelon pattern, diverging from the main zone and apparently dying out in the walls. Many veins or groups of veins change strike slightly along the zone so that they swing to the east, northeast, or northwest, leave the main vein and die out in the walls. In a few places, such as 470 feet west of the New shaft on the 600 level and 100 feet southwest of the New shaft on the 500 level, the structure within the vein is strongly divergent from the overall trend. At or near these places the main vein branches into two major splits separated by a horse of wallrock.

Above the 400 level between points in the drift about 500 and 800 feet west of the New shaft, the north vein was apparently quite strong and continuous, and it is reported to have been stoped to the surface (pl. 14, longitudinal projection). Company maps show that on the 400 and 373 levels the vein is somewhat discontinuous and contains three lenses of vein material that range in length from 70 feet to more than 300 feet and that are as much as 20 feet wide. They are enclosed in a wide altered zone that contains many narrower veins that generally parallel the main structure. Below the 400 level, a large body of vein material extends about 800 feet along the drift on the 500 level and more than 1,000 feet along the drift on the 600 level; a large horse of altered wallrock within the vein extends above the 500 and below the 600 level. The wide, strong north vein tends to pinch out, but the structure continues on as a broken and altered zone containing many small veinlets and numerous faults, probably of small displacement.

The chief sulfide minerals in the north vein in their probable order of abundance are pyrite, galena, sphalerite, some arsenopyrite, and chalcopyrite. Tetrahedrite and ruby silver have been reported from parts of the vein. Quartz and carbonate minerals are the chief gangue.

Most of the ore from the Gray Eagle mine came from two ore bodies on the north vein. Little is know about the western ore body, but it is reported to have been stoped from the 400 level to the surface. The eastern ore body was 10 to 15 feet wide, had a horizontal extent of from 70 to 250 feet, and had a vertical extent of about 250 feet. It was found in the 400, 500, and 600

[7] Most of the following material is from many reports and maps of the Basin Montana Tunnel Co., loaned by Mr. R. H. Mills of Spokane, Wash.

level drifts and extended from a little below the 600 level to above the 400 level. There is no surface indication of this ore body.

Available information indicates that in both directions along strike the ore bodies on the north vein become thinner and contain more gangue material, and that the vein beyond the limits of the ore bodies contains much quartz but only small pods and thin veinlets of ore minerals. The vein below the western ore body is wide and strong but was reported to be too low grade to be profitably mined. The eastern ore body is reported to be lower grade above the 400 level than below it, but no great change in mineralogy or structure was found. About 20 feet below the 600 level, however, the ore minerals in the eastern ore body end abruptly and in their place barren carbonate minerals extend down through the 700 level.

On the 700 level about 70 feet north of the carbonate-rich part of the north vein, a crosscut exposed a vein 4 feet wide carrying quartz, pyrite, arsenopyrite, and chalcopyrite. Samples of this vein from the crosscut are reported to have contained 0.08 to 0.14 ounce of gold and 8 to 20 ounces of silver to the ton, 1 to 2 percent copper, 0.5 to 1.3 percent lead, and a little zinc.

The south vein, about 100 feet south of the north vein and about parallel to it, is much weaker and narrower. It was first found in the 400-level crosscut from the surface and was developed for a few hundred feet on the 400, 500, and 600 levels. The vein consists primarily of gangue quartz and carbonate minerals containing bands of pyrite, galena, and sphalerite. A narrow ore body reported to be about 70 feet long extends at least as far down the vein as the 600 level and is reported to have been stoped from the 400 level to the surface. Whether or not the block between the 400 and 600 levels has been stoped is not known.

About 60 to 80 feet south of the south vein, a third vein is exposed only in crosscuts and short drifts. It is apparently a weak and discontinuous structure 3 feet or less wide, consisting mostly of quartz and pyrite. The vein probably splits from the south vein somewhere near the point where the south vein is cut by the 400-level adit crosscut.

Tenor.—A total of 11,200 tons of ore mined from 1901 through 1906 presumably came from the western ore body in the north vein and averaged 0.096 ounce of gold and 25.5 ounces of silver to the ton, and 18.2 percent lead; no zinc or copper was recovered. A total of 2,400 tons of ore mined in 1929 and 1930, presumably from the south vein or from the eastern ore body in the north vein, averaged 0.78 ounce of gold and 27.1 ounces of silver to the ton, 3.0 percent lead, 4.9 percent zinc, and 0.8 percent copper. A company report written when the eastern ore body was considered to be mostly mined out credits this ore body with a total production of 26,069 tons of ore that averaged 0.075 ounce of gold and 10.75 ounces of silver to the ton, 3.8 percent zinc, and 2.7 percent lead. The average content of recoverable metals from all of the Gray Eagle ore for which separate records are available is 22.4 ounces of silver and 0.09 ounce of gold to the ton, and 13.3 percent lead. Zinc was recovered from 5,072 tons of ore that contained 4.7 percent zinc, and copper was recovered from 5,702 tons that contained 0.71 percent copper. These figures include all of the ore from the north and south veins mined after 1901 with the exception of most of the ore from the eastern ore body below the 400 level.

Wallrock.—The Gray Eagle vein system cuts the middle unit of the Elkhorn Mountains volcanics in the large roof remnant, and the underlying Butte quartz monzonite. Most of the quartz monzonite on the dump has been intensely altered. The feldspars have been altered to sericite, and the mafic minerals have been almost entirely destroyed. Some of the rock has been replaced by very fine grained quartz. The rock is very light colored and appears bleached, but it still shows the original texture of cl. Molybdenite occurs as thin coatings on joints in fresh cl. Tourmaline is intergrown with pyrite in small pods in bleached and somewhat altered rock and in radiating groups of long needles along joints in fresh cl. The tourmaline is not finely intergrown with quartz as it is at Rimini.

Maps and reports of the Basin Montana Tunnel Co. indicate that a rock referred to as an aplite dike occupies the space between the north and south vein and extends a little to the north of and parallel to the north vein. Rocks of the alaskite group are extremely scarce on the dump, and it seems more probable that the "aplite dike" is a broad zone of intensely altered cl.

Radioactivity.—The radioactivity detected in 1951 was restricted to a small part of the dump, most of which was subsequently shipped to the East Helena smelter for its silver content. A man who formerly worked in the mine believed that the radioactive material came from the south vein on the 600 level.

A sample of some of the weathered radioactive vein material contained quartz, pyrite, a sooty black mineral, and a soft yellow mineral; it assayed 2.2 percent uranium.[8] An X-ray analysis of the sooty black mineral indicated that it is probably metamict pitchblende. Spectrographic analysis of an impure sample of the yellow material showed that it contains major iron and silicon, minor uranium, calcium, magnesium, aluminum, and manganese, and a trace of zirconium. A second sample contained sooty black material intimately mixed

[8] Alice Caemmerer and Mary E. Thompson, analysts.

with pyrite and associated with gray crystalline quartz. The sample with quartz removed contained 40 percent equivalent uranium,[9] and the sooty black material was identified as uraninite.

MORNING GLORY MINE

The Morning Glory mine (98), in the valley of Cataract Creek at its confluence with Uncle Sam Gulch in sec. 33, T. 7 N., R. 5 W., is at the western end of the Comet–Gray Eagle shear zone. The veins were found about 1920 by prospectors looking for an extension of the Comet–Gray Eagle zone.

The mine is developed by an adit at the level of a mill site, an adit 66 feet higher, and an underground shaft from the mill site adit (pl. 15). The upper adit and the shaft are inaccessible.

Two sets of veins are exposed in the mill-site level and in the level above. The stronger set, which strikes N. 55°–65° W., comprises two main ore-bearing veins about 6 to 18 inches wide and many smaller and less continuous veins. About 140 feet from the portal of the mill-site level a small but very high grade ore body was found in the northeastern wall of the vein at a point where several smaller veins split from the main vein and trend more to the east. Northeast-trending veins branch from the northwest-trending veins and are generally narrower and less persistent.

The chief ore minerals are fine-grained galena and dark sphalerite in bands cutting through the altered wallrock. The ore minerals are accompanied by very fine grained gray to coarser grained milky quartz, locally abundant carbonate minerals, and some pyrite. The carbonate minerals cut and replace the sulfide minerals.

Most of the wallrock on the mill-site level has been partly or wholly altered to clay minerals and sericite. Near veins, sericite is the dominant alteration product, but farther from the veins clay minerals are more abundant. All the altered rock seems to be related to veins or joints in the wallrock.

According to Mr. Kenneth Curtiss, owner of the mine, the galena- and sphalerite-bearing vein material from the northwestern veins is high-grade silver ore. During the years 1945 to 1947, 507 tons of ore was shipped and yielded 0.18 ounce of gold and 28.3 ounces of silver to the ton. Ore in which carbonate minerals are abundant contains less galena and sphalerite and is very low in silver.

HOPE-BULLION PROSPECT

About half a mile east of the Comet mine in sec. 6, T, 6 N., R. 4 W., an intensely altered zone in Butte quartz monzonite was explored by the Hope-Bullion prospect (101). The locality is at the intersection of the Comet–Gray Eagle zone and a major split from the zone. Between 1951 and 1953 a shaft 38 feet deep was deep was sunk in wallrock. Previously some trenches had been dug and a short crosscut driven a few feet below the outcrop.

The rock is intensely altered for a width of more than 50 feet, and much of it is obscured by deep weathering and hillwash. A zone about 10 feet wide contains many discontinuous quartz lenses. The trenches expose sparse cerussite, galena, pyrite, and sphalerite in intensely altered quartz monzonite.

MONO GROUP OF MINES

The Mono veins are northwest of Boulder Valley, near the eastern end of the Comet–Gray Eagle zone. Near the center of sec. 4, T. 6 N., R. 4 W., they begin to diverge from the N. 75° W. trend of the major zone until they strike N. 65° E.; and they can be traced in the latter direction for about 2 miles. Most of the mining has been done on the northernmost of four parallel veins on the Mono and East Mono claims.

The Mono mine (107), which has been idle for many years, consists of three shafts, now caved, and four short adits. Each shaft has a fairly large dump. The production is unknown, except for one shipment of lead ore and siliceous silver ore in 1919, which probably came from one of the dumps. The ore minerals, mostly very fine grained, are black sphalerite, galena, pyrite, tetrahedrite, and chalcopyrite. They occur in a gangue of gray to white quartz and carbonate minerals. Veinlets of carbonate minerals and some of the quartz cut and replace galena and sphalerite. Many of the carbonate veinlets contain fine-grained pyrite. Most of the wallrock on the dumps is intensely altered to sericite and contains disseminated pyrite and many small veinlets and irregular masses of quartz.

The relative abundance of ore minerals on the dumps, estimated as percent of total sulfides, is: pyrite, 35 percent; galena and sphalerite, 30 percent each; chalcopyrite and tetrahedrite together, about 5 percent. A sample of vein mineral from one of the dumps, thought to be representative of the ore, contained 0.36 ounces of gold and 17.1 ounces of silver to the ton, 13.8 percent lead, 0.9 percent copper, 10.2 percent zinc, and 0.2 percent manganese.

Northeast of the Mono mine, in sec 3, T. 6 N., R. 4 W., is another caved shaft on the northernmost vein of the Mono group (108). The sulfide minerals on the dump are all partly oxidized, and the gangue contains some chalcedony. Disseminated siderite in wallrock that

[9] R. E. Kellagher, analyst.

has been altered largely to clay minerals appears to be pseudomorphous after one of the feldspars.

About 1,000 feet northeast of this caved shaft are two short crosscuts about 40 feet apart vertically and another shaft (109). The upper crosscut and the shaft are caved at the surface; drifts on the vein from the lower crosscut are also caved. A wide altered zone, crushed and sheared by strike faulting, is cut by irregular branching bands of vein material, some of which are at least 1 foot wide. The order of abundance of ore minerals in the veins, estimated from dump material as percent of total sulfides, is: pyrite, 80; sphalerite, 10; galena, 5; and chalcopyrite, 5. The gangue is milky quartz, much of it the comb variety, and altered wallrock.

BISMARK-VAN ARMIN SHEAR ZONE

AUSTRALIAN MINE

The Australian mine (102) is in secs. 31 and 32, T. 7 N., R. 4 W., along the northern split of the Comet–Gray Eagle zone about 1¼ miles east of the Comet mine. The deposit is reported to have been discovered in 1873 and worked until 1895, and the mine is popularly credited with a total production during this period of ore worth $500,000. From 1911 to 1919 it was sporadically worked, producing less than 1,000 tons. No production has been recorded since 1919.

The mine is developed by 3 short adits on the eastern slope of a ridge and 2 shallow shafts on top of the ridge. The highest tunnel and the shafts are caved. The middle adit is about 130 feet long, and the lowest adit is said to be 285 feet long; both cut through a quartz latite dike to the vein.

The vein is 3 to 6 feet wide, strikes about N. 75° E., and dips vertically. Along its south side the vein is intruded by a dike of quartz latite at least 40 feet wide. In the middle adit the vein is separated from the dike by about 15 feet of altered and sheared cl, but in the lower adit the dike is adjacent to the vein, and both the dike and the vein are intensely sheared and broken.

The chief sulfide minerals on the dumps of the shafts and on the dump from the lowest adit are:

Mineral	Percentage of total sulfides	
	On shaft dumps	On lowest adit dump
Pyrite	60	40
Sphalerite	20	15
Galena	10	40
Arsenopyrite	7	2
Chalcopyrite	3	3
Total	100	100

Part of the difference in the proportions of the minerals from the two localities can be accounted for by the possibility that some of the material from the shafts was rejected by sorting; however, it seems very likely that the proportions also reflect differences in the vein along strike.

Some of the galena and sphalerite are cut by veinlets of pyrite and veinlets of quartz, many of which follow the cleavage of the galena or the sphalerite. Some of the pyrite is in turn cut by veinlets of quartz. Quartz and altered wallrock are the chief gangue materials.

BISMARK MINE

The Bismark mine (103) is in sec. 32, T. 7 N., R. 4 W., just east of the Australian mine and on the same vein. Two adits extend eastward into a ridge.

Recorded production from the mine is 1,342 tons of ore that yielded 258 ounces of gold, 20,417 ounces of silver, 28,840 pounds of lead, and 540 pounds of copper. No production is recorded for before 1922 or after 1939.

The Australian-Bismark vein, where exposed in the workings of the Bismark mine, strikes N. 75° E. and dips 65°–89° N. The upper adit follows the vein and is caved about 260 feet from the portal; according to an old map, it continues eastward for an additional 150 feet (fig. 47). A block of ore extending about 40 feet on each side of a raise was stoped above the adit for about 60 feet to the surface. Other smaller stopes which old maps show above the adit total about 245 feet in length. The lower adit, which is caved near the portal and is of unknown length, apparently is a lateral south of the vein.

From the portal of the lower tunnel to the top of the ridge and beyond, the vein is bordered on the north by a quartz latite dike that was intruded along it and in places was injected into it. Movement on a fault parallel to the vein has broken the vein and intensely sheared parts of the dike. The width of the vein is not definitely known, but in the upper tunnel the part of the vein south of the dike is as much as 15 feet wide, and on the surface the vein is about 10 feet wide. According to an old mining report, a crosscut driven from the creek level in 1892 ended in a dike. The vein where found in the crosscut was reported to be of quartz and 8 feet wide.

The ore is chiefly quartz, galena, and sphalerite, but some in the upper adit is oxidized. The average metal content of the ore is about 0.19 ounce of gold and 15 ounces of silver to the ton, and a little lead and copper. Some ore contained 0.32 ounce of gold and 20 ounces of silver to the ton, 10 percent lead, and 0.5 percent copper.

The Butte quartz monzonite south of the vein and lenses between parts of the vein are intensely altered to

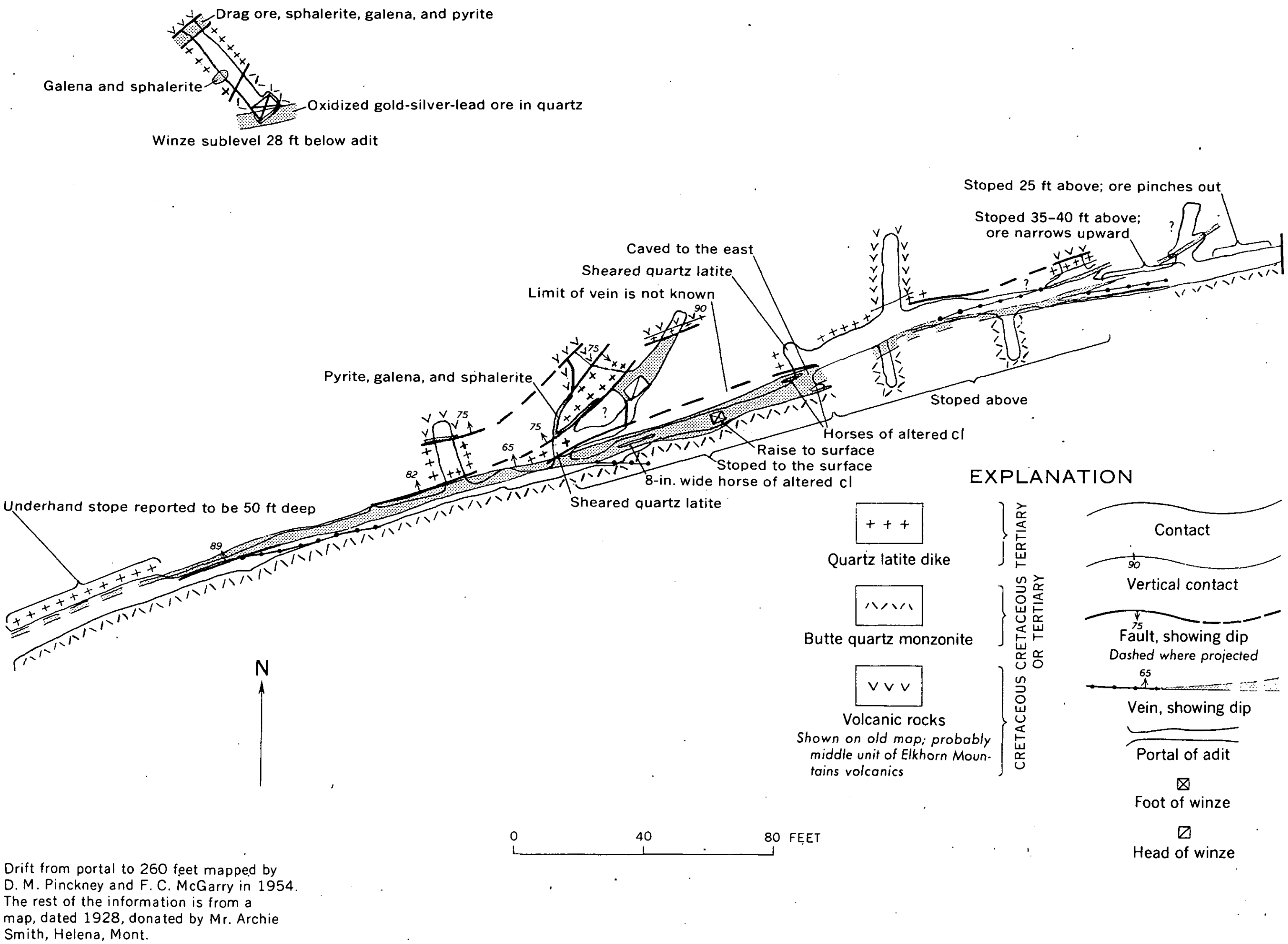


FIGURE 47.—Geologic map of part of the Bismark mine, Jefferson County, Mont., showing vein intruded by quartz latite dike.

clays and sericite. The sheared quartz latite dike north of the vein contains much gouge but is not hydrothermally altered.

Three nearly parallel, steeply dipping veins are exposed on top of the ridge east of the mine. The Australian-Bismark vein is the northernmost. The middle vein is a mineralized and altered zone in cl that has not been explored. The southernmost vein, called the Van Armin vein, has been partly explored by the workings of the Van Armin mine (104) to the east.

VAN ARMIN MINE

The Van Armin mine (104) is in sec. 32, T. 7 N., R. 4 W., about 2,000 feet east of the Bismark mine. It produced $480,000 worth of ore, according to popular reports, and was last worked in 1896. The adit level, said to be over 900 feet long, was being reopened in 1956 by Messrs. Smith and Sporrow of Helena. A shaft extends downward 150 feet from the surface to the adit level; stopes up to 6 feet wide and several raises are also reported.

The adit follows a strong quartz vein that is as much as 8 feet wide, strikes N. 80 W., and dips steeply south or is vertical. The wallrock is altered cl; a sericitic zone extends outward for several inches to about 2 feet from the vein, and an argillic zone extends several feet farther. From the portal of the adit to an ore body west of the shaft the vein is almost entirely coarse milky quartz. The ore body, which is reported to be about 200 feet long, has been stoped only above the adit, and the vein may contain ore below the adit level under the old stopes.

The ore is chiefly galena and sphalerite with a minor amount of chalcopyrite. In ore from near the stopes galena is about three times as abundant as sphalerite. Both sphalerite and galena are in ragged patches surrounded by coarse milky quartz, and the sphalerite is intensely cut by quartz stringers. According to an old map of unknown origin, carload lots of ore from the Van Armin mine contained 50 to 75 ounces of silver to the ton and 50 to 60 percent lead.

WILBER SILVER MINE

The Wilber Silver mine (105) is in sec. 32, T. 7 N., R. 4 W., about 1,000 feet northeast of the Van Armin mine. During the years 1927–29 and 1939–40 it produced less than 500 tons of ore. Its workings, all inaccessible, include a crosscut to the quartz vein near the western end of the claim, a shaft on the vein about 1,000 feet east of the crosscut, and an adit about 300 feet east of the shaft.

The vein, which strikes N. 85° E. and is vertical, is about 4 feet wide at the shaft and at least 1 foot wide at the adit. It is in altered Butte quartz monzonite close to the roof pendant and probably is an eastward extension of the Australian-Bismark vein. Ore minerals are galena, sphalerite, pyrite, and chalcopyrite. The ore contains approximately one-third of an ounce of gold and 12 ounces of silver to the ton, about 12 percent lead, and a little copper.

EVA MAY MINE

The Eva May mine (77) is on the west side of Cataract Creek in sec. 22, T. 7 N., R. 5 W. A 50-ton mill was built at the mine in 1900, and mining continued until about 1910. A past production of $2 million worth of ore is reported by the present owner. The mine workings consist of a shaft 1200 feet deep, drifts mostly to the west at approximately 100-foot intervals down to the 600-foot level, and levels at 800 and 1,200 feet (Pardee and Schrader, 1933, p. 295). In 1952 the 100-foot or King tunnel level was reopened and extended westward to explore the upward extension of ore bodies mined below the 200 level west of the shaft.

The Eva May vein is a quartz vein in a wide fractured and altered zone that extends nearly continuously for about 6 miles to the west. Old newspapers report that the vein is about 40 feet wide in most parts of the mine where the wallrock is Butte quartz monzonite. On the King tunnel level the vein narrows considerably where the wallrock is alaskite. The vein contains gray to milky quartz, pyrite, and differing amounts of galena, sphalerite, arsenopyrite, and chalcopyrite, as well as a little tourmaline in places. Four ore bodies, one east of the shaft and three west of the shaft, range from 80 to 200 feet in strike length. Two of those west of the shaft are reported to be 6 to 15 feet wide and were stoped between the second and fourth levels. Above these ore bodies, on the King tunnel level, the vein is very low grade and gives no indication of the ore bodies only 100 feet below. Apparently the same is true of the vein on the 1,200-foot level below the ore bodies (Billingsley and Grimes, 1918, p. 312).

MINNEAPOLIS MINE

The Minneapolis mine (83), in sec. 4, T. 6 N., R. 5 W., consists of 1 shaft, 1 adit, and 2 crosscuts to the vein. In 1929, according to an old map, the lower crosscut was 425 feet long and the upper crosscut was caved 270 feet from its portal; from each crosscut level, two short drifts followed the vein (pl. 16). The mine is now inaccessible. Production is not known, except that it was more than 600 tons.

The vein is a structurally complex mineralized zone more than 120 feet wide in the lower crosscut. The overall strike of the zone on the surface is about N. 75° E., and the Manhattan (84) vein is probably an extension of the zone. The vein is mostly gray to milky quartz; pyrite, sphalerite, and galena are concentrated in bands up to 6 feet wide and are also scattered through the quartz. Most of the bands strike nearly east except in the northern part of the zone where many thinner bands and veinlets strike N. 50°–60° E. Most of the sulfide minerals are in the stronger bands in the southern and central parts of the vein. Available maps suggest that the northeast-trending bands and veinlets branch from the strong central part of the vein west of the crosscuts.

The southern and central parts of the vein are separated by a quartz porphyry dike that is brecciated and cemented by gray quartz and calcite (?) along its north side. The vein is bordered on the south by a steeply dipping fault zone and is cut by a fault that strikes north to northwest and dips 52°–80° W. In places the ore contains 15 to 20 ounces of silver per ton and about 9 percent lead. Parts of the vein probably contain considerable zinc.

MANHATTAN MINE

The Manhattan mine (84) is in sec. 4, T. 6 N., R. 5 W., a few hundred feet east of the Minneapolis mine. Drifts and crosscuts totaling several hundred feet in length (fig. 48) explore what is probably an extension of the Minneapolis vein zone. In the adit drift, a vein up to 3½ feet wide that strikes east and dips steeply is exposed for 270 feet east from a point near the portal. A second vein, reached by a crosscut that extends northward 115 feet from the drift, strikes northeast and has been stoped for more than 120 feet along a drift on it. This vein is cut off at its northeastern end by a strong northwest-trending fault. Workings extend beyond this point but are inaccessible. Vein material on the dump consists of quartz and galena with some sphalerite, pyrite, and malachite.

HIGH ORE MINE

The High Ore mine (88), patented as the Montana Consolidated claim, is in sec. 2, T. 6 N., R. 5 W., on the west side of High Ore Creek. No record of production is available. The mine consists of a crosscut 1,600 feet long (driven in about 1898), a 200-foot drift, two stopes, and a winze on a vein near the face of the drift. The crosscut intersects several veins (pl. 17) that consist of silicified Butte quartz monozonite and stringers of white to bluish-gray quartz; some veins contain sparse pyrite, galena, and chalcopyrite. About 1,600 feet from the portal the crosscut intersects a vein at least 10 feet wide of dark-blue quartz with white quartz stringers containing sparse pyrite and galena. This quartz vein, which strikes approximately N. 60° E. and dips 65°–70° SE., is the downward extension of a large chalcedony-vein structure that crops out 900 feet above it on top of the ridge west of the mine portal. The drift follows the vein about 200 feet to the southwest. On the surface the vein is intensely silicified fine-grained quartz monzonite cut by many light-gray chalcedony stringers from 0.1 inch to 12 inches wide; some of the stringers contain a little milky quartz, and a few are cut by small brown-weathering carbonate stringers. The rock in the vein zone is intensely brecciated and faulted; most of the fragments are blocky and less than 1 foot in largest dimension.

Anomalous radioactivity was detected in the mine in October 1951. No abnormal radioactivity was found on the dump or along the outcrop of the vein. Radiometric traversing of the tunnel, however, disclosed a gradual increase in radioactivity from normal background at the portal to 10 times normal background a few tens of feet from the face. Beyond this point the increase is more rapid, and at the face the reading is 30 times background. The source of the radioactivity could not be determined nor could any samples of radioactive rock be found.

BALTIMORE MINE

The Baltimore mine (89), on the west side of Boomerang Gulch in sec. 7, T. 6 N., R. 4 W., includes 8 levels and 1 shallow shaft in a vertical interval of about 400 feet (pl. 18). The mine was worked in the 1880's and intermittently thereafter until about 1930. The main development was done before 1915. Since 1930 a few short adits have been driven near the upper workings, and a few hundred tons of ore mined from them. Much of the following information is taken from old maps and reports. The fieldwork for the maps and reports was done in 1915 and 1930.

From 1903 to 1948 the mine produced a total of 22,823 tons of ore, from which were recovered 1,729 ounces of gold, 273,642 ounces of silver, 1,260,509 pounds of lead, 208,750 pounds of zinc, and 270,997 pounds of copper. Production before 1903 is not known but probably was several thousand tons.

The overall tenor of ore produced since 1903 is 0.076 ounce of gold and 12 ounces of silver per ton, 0.59 percent copper, and 2.7 percent lead. Much of the zinc and copper was not recorded. Several samples from some of the stopes, taken across a width of 4 to 6 feet, contain from 1.5 to 2.9 percent copper and average about 11 percent zinc according to available maps.

The rocks at the mine are largely Butte quartz monzonite but include some alaskite. A postore dike of quartz latite has been intruded along the southeastern side of the vein and cut part of the vein.

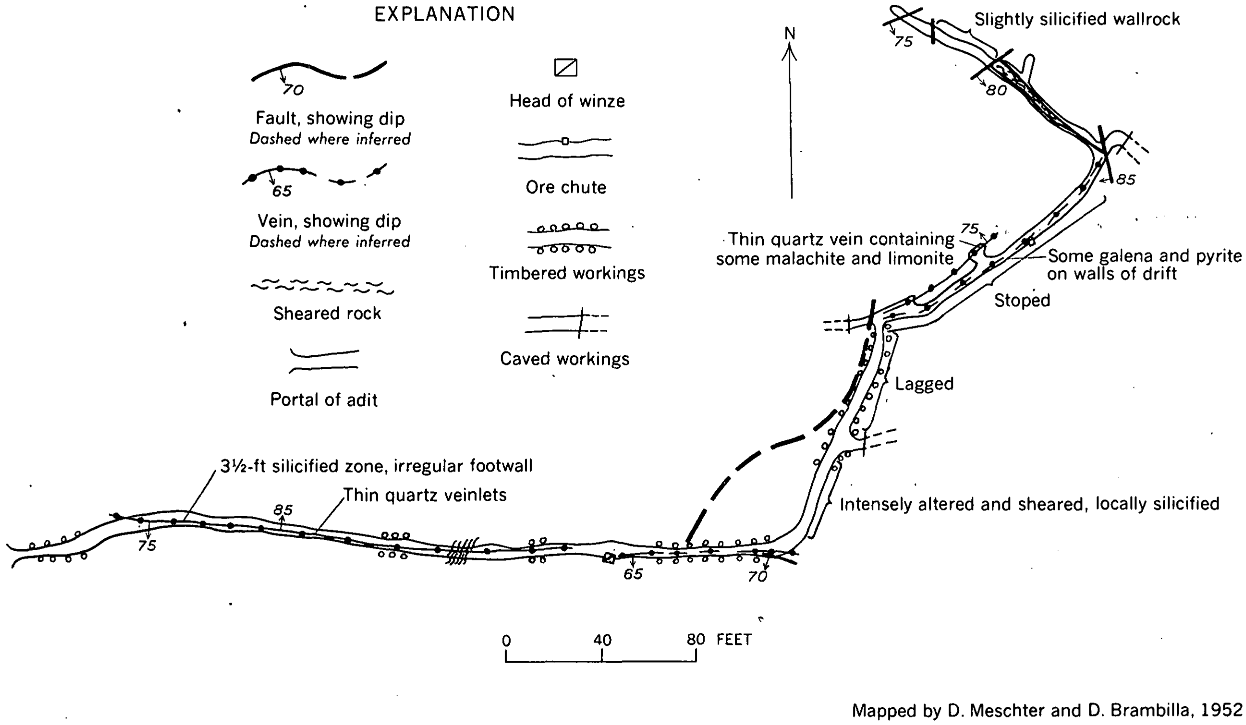


FIGURE 48.—Geologic map of the Manhattan mine, Jefferson County, Mont.

The Baltimore vein is a wide, structurally complex zone that strikes northeast and is nearly vertical. The southwestern part of the zone, exposed in tunnels 1, 2, and 3, is a well-defined vein 8 feet wide that strikes about N. 70° E. It consists largely of quartz with pyrite, some chalcopyrite, and a little chalcocite. The northeastern part of the zone strikes about N. 55° E. and is composed of three or four main veins from which many smaller veins diverge to the northeast and swing northward in a complex horsetail manner. This horsetail part of the vein zone is as much as 200 feet wide on the No. 4 tunnel level. Its length is not known, but the pattern of veins in the Hope and No. 1 tunnels indicates that it may be 400 feet long. The major veins are 6 to 10 feet wide; northeastward, three veins merge to form a single vein that is mineralized across a width of about 45 feet in the Block stope (pl. 18). The southeasternmost vein in the vein zone is cut and separated from the rest of the veins by the postore dike (section *A–A′*, pl. 18) and is known only on the 40- and 90-foot levels.

Five main fault zones cut the Baltimore veins into segments. Four of them, the West, Middle, Stope, and East faults, strike northeast; the Middle and Stope faults dip about 40° to 60° SE. in most places; the West and East faults dip steeply except on the lower levels in the western part of the vein zone where the West fault flattens. Movement on the four northeast-trending faults was probably not more than a few tens of feet. The Middle fault offsets the veins in the Hope tunnel, but the vein segments in the walls of the fault are not moved completely apart. The Stope fault offsets the veins as much as 50 feet normal to the strike of the fault and cuts off the ore in the bottom of the Black stope near the North fault, but about 80 feet to the southwest the vein crosses the Stope fault with no apparent offset (sections, pl. 18).

The fifth fault zone, the North fault, strikes N. 70° W. and is cut and offset by the Middle and Stope faults. The veins terminate against it, and, although drag ore was found in the fault on the No. 4 level, no northeastward extensions of the veins have been found beyond it. A well-defined vein north of the North fault and parallel to it dips steeply northeast; where exposed in the No. 5 tunnel level the vein is about 5 feet wide. The North fault appears to be the southeastward extension of an altered and mineralized zone that extends nearly a mile about N. 70° W. from the Baltimore mine.

The largest ore body in the mine is in the complex northeastern part of the vein zone near the North fault. This East ore body contained much sphalerite with considerable galena and pyrite and some arsenopyrite and chalcopyrite in a quartz gangue. In the Black stope (pl. 18) the body was mined to the limits of the vein walls, about 45 feet apart, including a band of low-grade quartz 5 feet wide. The sulfide minerals were arranged in crude layers, and the layers that were high in lead and silver and low in zinc supported much of the mining prior to 1915. Later the remaining ore was taken out above the Stope fault. Southwestward, the East ore body splits into three narrower bodies, which were mined in the Hanging-wall, Middle, and Footwall stopes. The downward projection of the ore body in the Black stope is cut off by the Stope fault above the No. 4 level, but the ore in the Footwall and Hanging-wall stopes continues downward across the fault to the No. 4 level. The West ore body, in the southwestern part of the vein zone, is mostly pyrite and quartz with some chalcopyrite and a little chalcocite. The ore body is about 100 feet long and was mined from the No. 2 level to the surface. Below the No. 2 level the vein is low grade.

Two smaller ore bodies were mined from the upper levels. One of these, on the strand of the vein southeast of the dike, was stoped above the 90-foot level but was not followed downward. On the No. 4 level its position is occupied by the postore dike, but a little ore may remain above the dike. The other ore body is along the N. 70° W. vein north of the North fault. This vein was stoped from the No. 5 level to the surface and may be partly stoped below the No. 5 level. It is possible that an extension of the northwesternmost crosscut on the No. 4 level would find the downward extension of this vein on the other side of the North fault.

The size and shape of the East ore body and the structure of the veins, faults, and postore dike were not understood by the operators who did most of the exploration before 1915, and for this reason ore was undoubtedly left in the mine. Any future sustained operation, however, would probably require finding the downward and northeastward extensions of the East ore body. Between 1915 and 1930 a drift was driven on the No. 4 level northeastward to the North fault in an effort to find the downward extension of the Black stope ore below the Stope fault, but the drift became lost in the horsetail strands and was probably a little too far to the northwest. A crosscut to the southeast would have tested the block of ground, about 50 feet high, between the No. 4 level and the Stope fault, but no crosscutting was done. If ore were found here it could be followed downward by winzes. Where cut in the Hope tunnel the vein is low grade and broken by the Middle fault, but it was not explored across its entire width and its limits are not known. Crosscuts driven northwestward and southeastward from the Hope tunnel to the limits of the vein, both above and below the Middle fault, might find high-grade veins that are the downward extension of the East ore body in the deepest part of the mine.

The North fault cuts off the East ore body at its widest place, and drag ore was found in this fault on the No. 4 level, but apparently no attempt has been made to find the extension of this ore body northeast of the fault. Part of the area may be underlain by the postore dike. Outcrops are lacking, but this area could be prospected by soil sampling followed by trenching. If the northeastward extension of the vein is found, a crosscut could be driven to it from the No. 4 level, and, at greater depth, the Hope tunnel could be extended to it. In future exploration all veins should be explored to their walls and the walls drilled or crosscut to be certain that no ore is missed.

FREE ENTERPRISE MINE

The Free Enterprise mine (90), in sec. 19, T. 6 N., R. 4 W., was originally called the Silver Bell silver prospect. It was reopened after uranium was discovered there in 1949 (Thurlow and Reyner, 1950), and about 150 tons of uranium-silver ore was produced in 1951 (Roberts and Gude, 1953b, p. 147). In 1952 a passenger elevator was installed so that people could be taken into the mine for radioactive treatments.

The workings consist of two shafts—a mining shaft 150 feet deep and an elevator shaft 80 feet deep—drifts at depths of 80, 100, and 140 feet, and small stopes, mostly above the 80-foot level. The drifts extend from the mining shaft for 80 to 170 feet to the southwest and 150 to 180 feet to the northeast.

Roberts and Gude (1953b) describe in detail the geology in and near the Free Enterprise mine. A chalcedony vein containing some microcrystalline quartz strikes N. 65° E. and dips from 75° N. to 90° in Butte quartz monzonite, which is intruded by at least two flat-lying sheets of alaskite up to 25 feet thick. The vein ranges in width from 2 inches to 3 feet. Uranium minerals are not found at the surface and the intensity of radiation at the surface is low (Roberts and Gude, 1953a, 1953b). In the mine, metatorbernite, meta-autunite, and other secondary uranium minerals are disseminated in both the vein and the adjacent quartz monzonite, and the vein contains local small pods of pitchblende. Associated with the uranium are very small amounts of pyrite, galena, ruby silver, argentite, native silver, molybdenite, chalcopyrite, arsenopyrite, barite, and limonite. Ore shipments contained 5 to 133 ounces of silver per ton and 0.14 to 1.61 percent U_3O_8 (Roberts and Gude, 1953b, p. 147).

PILOT AND SILVER STAR MINES

The Pilot and Silver Star mines (93) worked a vein in sec. 4, T. 6 N., R. 4 W. They were active before 1900, but production is unknown. In recent years the vein has been reworked through a shallow shaft on the Pilot claim; production is recorded as less than 100 tons. The Silver Star shaft is now caved, and no information about the mine is available.

The main vein exposed in the Pilot shaft is a zone 3–5 feet wide containing many massive quartz veins in a much wider zone of sheared and altered rock. The vein strikes N. 80° E. and is nearly vertical; many smaller veinlets split from it and strike northeastward in horsetail fashion. Near the Pilot shaft an ore body was stoped to the surface.

The vein is oxidized. Pyrite, galena, sphalerite, malachite, and limonite, in a gangue of milky quartz, chalcedony, and altered wall rock, constitute the ore. For about 500 feet to the east and west of the Pilot shaft the vein is radioactive. Metatorbernite was found in prospect pits in the oxidized, iron-stained outcrops of silicified rock near the Pilot shaft.

Several short adits (94) in sec. 3, T. 6 N., R. 4 W., explore the eastern extension of the Pilot–Silver Star vein zone, which strikes N. 75° E. and is vertical. At the surface the zone consists of siliceous veins in altered and weathered rock. The vein material is mostly fine-grained to chalcedonic gray, black, and brown quartz. Carbonate minerals are conspicuous, and the veins contain some fine-grained galena, sphalerite, and pyrite.

BOULDER CHIEF MINE

The Boulder Chief mine (95), in sec. 27, T. 7 N., R. 5 W., is developed by a shaft and an adit, both of which are now inaccessible. These workings apparently explore a small east-trending vein. A small amount of lead, silver, and copper was produced between 1913 and 1917. The shaft is collared in prebatholith volcanic rocks, but most of the rock on the dump is intensely altered alaskite or quartz monzonite. Sulfide minerals identified from dump samples are galena, sphalerite, pyrite, and arsenopyrite. No radioactivity was detected on the large dump from the shaft; however, several small pits upslope east of the shaft showed weak radioactivity. A sample of the most radioactive material, which consisted mostly of brown, iron-stained quartz, contained 0.016 percent equivalent uranium and 0.010 percent uranium.

VIRGINIA C. MINE

The Virginia C. mine (96) is in sec. 28, T. 7 N., R. 4 W., ¼ mile north of Amazon. The mine has one adit, which was reopened and accessible in 1954.

The principal vein dips gently west and southwest along the bottom of a sill intruded from the batholith into the middle unit of the Elkhorn Mountains volcanic rocks (fig. 49). Thickness of the vein ranges from a few to 30 inches. Two smaller veins parallel the principal vein. Where branches of the veins extend into either type of wallrock they become weaker. The veins contain mostly quartz, pyrite, limonite, and arsenopyrite, but they also include some galena and sphalerite.

Layering in the volcanic rocks dips about 6° W. The bottom of the sill tends to follow the layering but in at least two places cuts sharply across it.

ROBERT EMMETT MINE

The Robert Emmett mine (97) is in sec. 27, T. 7 N., R. 4 W. 1 mile northeast of Amazon. It was the first mine in the area to use electricity; power was installed in 1908 (U.S. Geol. Survey, 1919, p. 374). Production is unknown. A shaft is reported to be at least 500 feet deep and to have 800 feet of level workings at the bottom (Montana Inspector of Mines, 1911–1912, p. 73); other levels are at depths of 200 and 350 feet. A crosscut 600 feet long reaches the shaft at a depth of 170 feet, and some ore was stoped on the crosscut level. A drift east from the crosscut is caved. The depth of a second, older shaft is unknown. Both shafts are caved at the collar. A vein at the collar of the newer shaft strikes N. 74° W. and dips 84° N. The vein is at least 5 feet wide and is bordered by 4 feet of gouge. A vein in the crosscut strikes N. 79° W., dips 75° N., and is 7 feet wide. This vein does not project to the shaft collar, and is probably not the same vein that is exposed there.

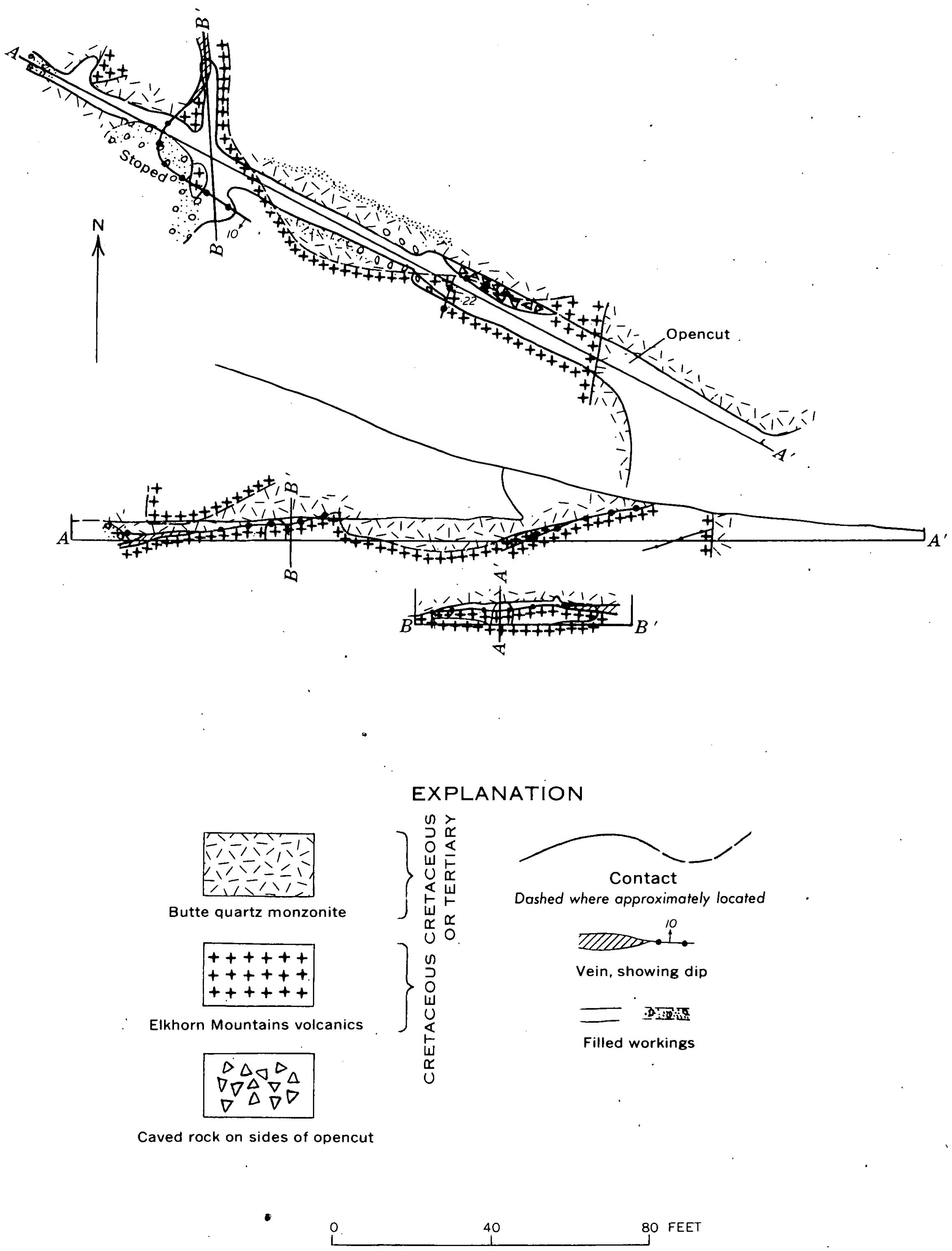
The most abundant minerals on dumps from both the shafts are quartz, chalcopyrite, and pyrite. Sphalerite and galena are less abundant. The dominant minerals from the vein in the crosscut are quartz and sphalerite; galena, chalcopyrite, and pyrite are also present.

CUSTER-HIAWATHA SHEAR ZONE

A wide fractured and altered zone that strikes N. 75° E. extends about a mile across secs. 3 and 4, T. 6 N., R. 5 W. It crosses the contact of the batholith with the Elkhorn Mountains volcanics without offsetting it. Ore has been produced from veins along this structure at the Custer mine (79), the Hiawatha mine (80), and the Red Wing mine (81), but the mines have not been worked for many years.

The Custer mine (79) consists of a shaft on top of a ridge and an adit on the vein about 150 feet lower and to the west. The adit is caved 270 feet east of its portal. The vein contains clear to milky quartz and scattered galena, sphalerite, and pyrite. It strikes N. 80° E., dips 75° N., and is 3 to 5 feet wide. Cross faults that strike north and dip west offset the vein a few feet.

The Hiawatha mine (80) consists of a 2-compartment shaft and 3 adits on a vein 3 to 6 feet wide containing clear to milky quartz, pyrite, galena, and sphalerite. The vein strikes N. 70° E. and dips steeply in the middle unit of Elkhorn Mountains volcanics.



Mapped by D. M. Pinckney and F. C. McGarry, 1954

FIGURE 49.—Geologic map and cross sections of the Virginia C. mine, Jefferson County, Mont.

The Red Wing mine (81) is near the eastern end of Custer-Hiawatha zone. Two adits were driven on the vein: an upper adit about 50 feet long and a lower adit 425 feet long. Small stopes extend above and below the lower adit level. From the face of the lower adit to a point about 220 feet east of the face the vein strikes N. 70° E. and dips 70°–80° N. Beyond this point, the vein merges with a more eastward trending zone containing several veins about 6 inches wide. The vein is mostly white to clear quartz but contains some sphalerite, galena, and pyrite.

MERRY WIDOW MINE

The Merry Widow mine (85) is in sec. 17, T. 6 N., R. 5 W., south of the Boulder River. It consists of two adits: an upper one, now caved at the portal, and a lower one, caved 490 feet from the portal. Two chalcedony veins on the surface strike N. 65°–75° E. and dip steeply. In the lower adit (fig. 50) a vein that strikes northwest and dips steeply is exposed from the portal to a point 420 feet southeast of the portal, where it merges into a zone of chalcedony and silicified rock as much as 30 feet wide. This zone is probably the downward extension of one of the two veins on the surface. Its south wall strikes N. 75° E.

OTHER MINES

Hattie Ferguson mine (78)

Location.—Western side of Cataract Creek in secs. 28 and 29, T. 7 N., R. 5 W.

Mine workings.—Shaft 140 feet deep (Knopf, 1913, p. 124) and two short adits near top of a ridge; 1,800-foot crosscut about 480 feet lower from a point near Cataract Creek.

Vein.—Strikes N. 75° W.; dips steeply.

Mineralogy.—Quartz, pyrite, galena, sphalerite, some chalcopyrite on upper dumps. Carbonate minerals abundant and sulfide ore minerals sparse on dump from lower crosscut.

Waldy mine (82)

Location.—Sec. 3, T. 6 N., R. 5 W., about 400 feet north of the Red Wing Mine (81).

Mine workings.—Two caved crosscuts to vein, 300 feet apart. Western crosscut probably about 185 feet long and 75 feet below outcrop; near outcrop, a stope to surface.

Vein.—Strikes east, dips 68° N.; oxidized. About 2 feet wide.

Mineralogy.—Vein material on dump of western crosscut is quartz, pyrite, galena, sphalerite, limonite, and lead carbonate; vein material on dump of eastern crosscut is mostly primary carbonate minerals.

Obelisk mine (86)

Location.—Sec. 15, T. 6 N., R. 5 W.

History.—Mined mostly before 1900; production unknown.

Mine workings.—Shaft, two short adits, a main tunnel level about 200 feet below the outcrop, and a winze that extends about 190 feet below the tunnel level (pl. 4). A large stope, 15 by 40 feet, tapered upward to a height of about 30 feet; three similar stopes along the winze at depths of about 50, 65, and 140 feet.

Ore body.—A mineralized conduit near the eastern end of an altered breccia pipe. (See p. 50.)

Mineralogy.—Fine- to coarse-grained sphalerite, fine to medium-grained galena, sparse pyrite and chalcopyrite.

Gangue.—Very fine grained quartz and, in places, some rhodochrosite and siderite.

Grade.—According to old records, ore body probably very rich in silver; several percent of lead and zinc, very little gold.

Locality 87

Location.—Sec. 10, T. 6 N., R. 5 W.

Mine workings.—Caved adit; two shallow shafts a few hundred feet southeast of adit.

Vein.—Strikes N. 51° W.; dips nearly vertically. Quartz-chalcedony vein up to 6 feet wide in shaft.

Mineralogy.—Outcrop of vein contains only coarse milky quartz and chalcedony. Vein material from adit contains quartz (chalcedony, galena, sphalerite, pyrite, limonite, malachite, azurite, native silver, and green and yellow earthy oxide minerals. Some vein material from adit is siliceous boxwork.

Wallrock.—Mostly rocks of the batholith, but includes some Elkhorn Mountains volcanics, probably from xenoliths, on dumps; all rocks are altered to sericite, clay, and silica.

Cleveland mine (91)

Location.—Sec. 5, T. 6 N., R. 4 W.

History.—Produced less than 100 tons 1920's; worked in recent years.

Mine workings.—Three shafts; the two western shafts are caved; the eastern shaft is on the vein and is flooded below 110 feet. Filled stopes extend a short distance from the shaft below a depth of 64 feet.

Vein.—Strikes N. 84° E., dips 77° S.; locally 5 feet wide.

Mineralogy.—Chiefly pyrite, galena, and quartz; some sphalerite and chalcopyrite.

Tenor.—Ore produced in 1920's contained about 12 ounces of silver per ton and 15 percent lead.

Locality 92

Location.—Sec. 5, T. 6 N., R. 4 W.

Mine workings.—Short adit and shallow shaft.

Vein.—Quartz and pyrite; strikes N. 86° E., dips 90°. Occupies a wide altered zone in cl about 1,000 feet south of the main part of the Comet–Gray Eagle shear zone.

Radioactivity.—Some material on the dump is slightly radioactive.

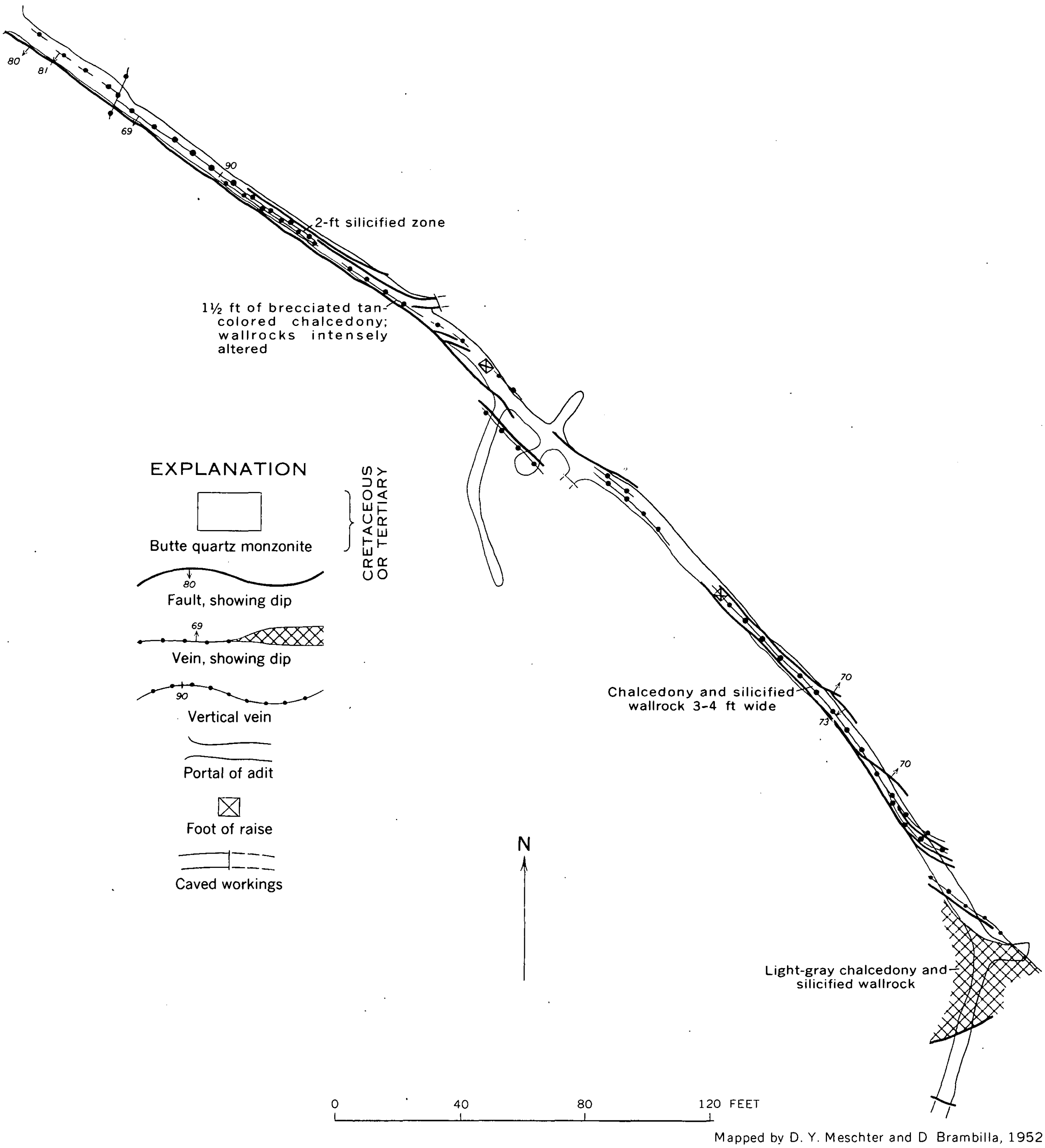


FIGURE 50.—Geologic map of the Merry Widow mine, Jefferson County, Mont.

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